WESTERN AUSTRALIAN INSTITUTION

OF

ENGINEERS.

PROCEEDINGS.

VOLUME I.

No. 1.

OCTOBER 1910.

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PROCEEDINGS

OF THE

WESTERN AUSTRALIAN

Institution of Engineers.

VOLUME I.—No. I.

OCTOBER, 1910.

PUBLISHED BY THE INSTITUTE,

AT THE HEAD OFFICE, PERTH.

1910.

Western Australian Institution of Engineers.

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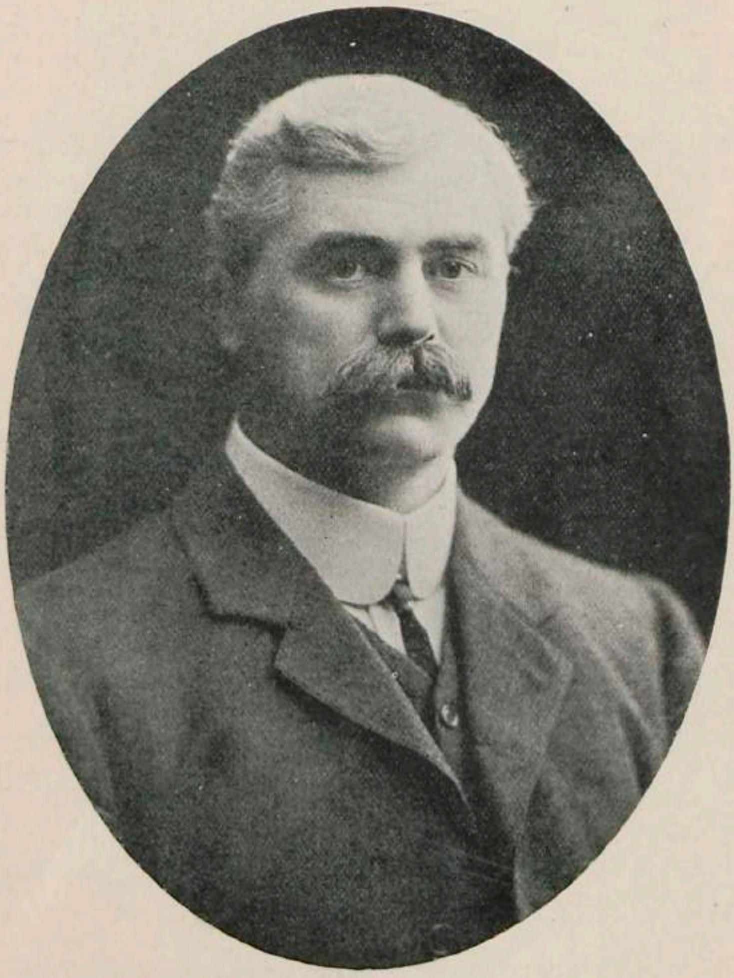


JAMES THOMPSON, B.E., M.Inst.C.E
President 1910-1911

VOL. 1. OCTOBER, 1910.

PROCEEDINGS—Western Australian Institution of Engineers.

PAPERS AND DISCUSSIONS.

GROWTH OF ALGÆ IN RESERVOIRS AND HOW TO TREAT IT.

By James Faulkner.

For some years, more especially since the water from the Redan-street artesian bore has been in use, a growth of algæ (spirrilum) has developed in the service reservoirs in King's Park. This always makes its appearance after the warm artesian water is put into use. The temperature is 100 degrees. The algæ quickly arrives at maturity, about the sixth day, and although it is harmless when it is decomposing (as it does every week) it imparts a violent taste and an aggressive smell to the water.

I had read papers dealing with the treatment of the water in *impounding* reservoirs for the destruction of the algæ, but we have no trouble with our impounding reservoirs in this respect. There are various reasons to account for this :—The algæ will not grow in water that has not a stable level. The water at Victoria reservoir only complies with this condition for a short time in the winter when the temperature is too low to encourage the propagation of the algæ, and during the winter it

does not grow in the service reservoirs. With the advent of the warm water the conditions that favor the propagation of the algæ are in full force. During the summer the water is travelling out of the service reservoirs as fast as it is travelling in. With an impounding reservoir to treat, the conditions are different, as the water could be stopped from going into consumption during the treatment if you have service reservoirs to keep up the supply, but if it is the water in the latter that has to be treated, then the operation appears to be much more difficult, because this is the water that is going into direct consumption from the heart through the mains which are the arteries, and is drawn off through the veins into the consumers' taps.

These considerations caused my early experiments to be of no effect, simply because I did not use a sufficient quantity of sulphate of copper to have any perceptible effect for fear that the consequences might be harmful to the consumers.

At the beginning of the summer of 1908 I asked the advice of the Government Analyst, and he, after seeing the conditions under which the treatment would have to be carried out, advised that a dose of four ounces of the copper salts should be used to one million pounds of water (one hundred thousand gallons), the full dose was four pounds, costing 1s. 4d. The salts were applied by enclosing them in a filter cloth and submerging this in one of the channels through which the warm water flows. It was gradually dissolved, the flow carrying it on into the reservoir, mixing the water thoroughly. This was quite successful. Within forty eight hours the algæ, which was a brilliant green color, turned to a shabby brown; it looked and felt like leather; the taste and smell had disappeared. There was often a green oily appearance on the surface of the water. This was caused by myriads of fragments of the algæ. This also disappeared, leaving the water clear and limpid.

I found it necessary to dose the water every week during the summer, and there were no complaints during this period. A dose of the sulphate only prohibits the growth for one week. Though the algæ cannot propagate without water it is also dependent for support from the walls which are concrete (it will grow on iron as well), it does not appear to be able to grow in the water separated from the walls. Noticing this fact, and also that where the salts came into contact with the concrete of the channel where it was applied to the water, a blue stain appeared, and that no growth was established on these spots, I concluded that a prepared or poisoned surface would prohibit the propagation of the algæ. To prove this I had a portion of the west and east walls of No. 1 reservoir (which is used as a settling tank, and in which the water level varies only a few inches, and that very slowly) washed with water in which a few pounds of the copper

salts had been dissolved. After it had dried the water was allowed to rise and the walls were kept under close observation. No growth appeared until the expiration of forty days. It, however, still grew on the walls below the part which had been treated, but not to the same extent. It was, however, found necessary to treat the water once a week during the summer of 1908-09. There were no complaints of anything that could be put down to the presence of algæ in the water, and many searches were made by the Government Analyst for copper, but always with a negative result.

After my experience, as herein, of the behaviour of the algæ, before commencing pumping for the season 1909-10 I had the walls of the service reservoirs to a depth of two feet from the surface washed with water that had a few pounds of the sulphate of copper dissolved in it. It was given ample time to dry. It was eighty days after commencement of pumping before any algæ appeared, and the growth has been very feeble all the summer, though the continued hot weather was distinctly favorable for its propagation.

As the growth was still in evidence below the treated portion, the water was treated each week. It is no trouble, and the expense for the salts was only 30s. for the season, during which time nearly 500 millions of gallons were consumed. Tests were made, as during the previous summer, to see if copper could be detected in the water, with negative results.

We so remove one of the principal objections to the use of artesian water, and in the light of our greater knowledge of the quantity and quality available, we can almost say that there is under Perth an inexhaustible supply of water. To make it appreciated by the consumer, it is only necessary to recognise the water from this source as a part of the permanent supply to the metropolitan area, and we shall then do those things that are necessary to overcome the consumers' conservatism in this matter.

I can conceive cases where the water in a tank may be rendered undrinkable by the algæ without the assistance of artesian water, and it may be useful to a resident of the back blocks, who may use sulphate of copper for other purposes, to know that if he puts 35 grains of the salt into two thousand gallons of water, mixes it well and lets it stand for twenty-four hours (it is not absolutely necessary) it will then be quite fit and safe for use.

I have not thought it necessary to go into the reasons why the water from one, two or three bores out of six will cause or promote the growth. For the biological and chemical history of the algæ I refer you to the Government Bacteriologist and Analyst.

ADHESION BETWEEN CONCRETE AND STEEL BARS.

By F. W. Lawson.

Some time ago the writer was in structed to make some tests in connection with the adhesion of steel bars and concrete, more especially dealing with the bars of the indented type.

The indented bars were cut off in convenient lengths and embedded in concrete blocks varying from 6 in. x 6 in. x 8 in. to 8 in. x 8 in. x 36 in. A fair length of bar in every case was allowed to project outside the concrete to enable a proper grip to be taken in the testing machine.

For the purpose of comparison round and square bars were inserted in similar blocks made under exactly the same conditions.

The concrete work was done by reliable men and can, therefore, be considered as being at least up to the usual standard.

In order to obtain results on an ordinary working basis, the proportions of concrete were mixed to No. 1 sewerage standard, which consists of one part cement, two of sand and four of stone. Records have been kept of the weight of the concrete per cub. ft., and it can be taken as 153 lbs., the actual figure being 152.6 lbs. per cub. ft.

The cement was obtained through the Government Stores from tested stack Saturn brand, and may, therefore, be taken as of being the highest quality.

The sand was obtained from a hill near the sewage treatment works, East Peith, and when tested gave the following result :—

Tensile strength (3-1) at 7 days, 239 lbs. per inch.
Do. standard sand, same cement, 287 lbs. per inch.
Insoluble silicates, 97.9 per cent.

The stone was obtained from Statham's Quarry, and was a fair sample of diorite, 1½ in. gauge, with the fine stuff over ⅛ in. left in.

The blocks were made between the 7th and 10th of May, 1909, and tests were carried out on or about August 17, consequently blocks were about twelve weeks old.

The concrete blocks were made in moulds and allowed to harden in the air, the surface being protected from the rays of the sun by bags, which were kept wet for about a fortnight after the blocks were made.

The concrete when inspected after the tests was a very good sample, showing the voids entirely filled, and from inspection of the bars after rupture it is evident that a good even contact was made between the metal and the steel.

In putting the blocks into the testing machine a special pair of dogs was made. These dogs were designed for the purpose of keeping any side pressure from taking place along the sides of the blocks, the whole of the strain being taken by a plate which was placed against the flat end of the block, and butted up against the turned in ends of the dogs, and the bar came through a hole in the centre of this plate. I was present when the first block was tested and also other blocks, and I am perfectly satisfied that there was no possibility of any gripping taking place around the concrete block in the testing machine. Tests were carried out at Midland Junction in the Standard testing machine and there was no probability of any shock or jar taking place when the pressure was first applied.

After the first block had been tested I arranged with the Engineer-in-Charge of the testing plant at Midland Junction to keep a record not only of the tension required to break adhesion between the concrete and the different varieties of bar used, but also to keep a record of the actual pull required to keep the bar moving after the first break in contract had been made. Diagrams weie taken and this infoima-tion compared with the results obtained by various other authorities.

The figures obtained by our local tests are to some extent different from those obtained by other experimenters, also from those in many of the text books on reinforced concrete work. Our results more nearly approach the figures given by Professor Warren, of Sydney University, from results of tests made by him.

The surface of the bars used was left in its natural condition; no attempt was made to disturb the skin of the bar or to clean off anything more than the loose rust and dust which had accumulated thereon. The bars were merely shaken, no wire brushes or anything of that nature being used.

In regard to the method of comparison adopted, the standard method of taking the mean surface area in sq. in. in contact with the concrete was used, and the comparisons were all worked out on this basis.

In five cases the tensile pull on the rod exceeded the elastic limit of the steel given by makers as 35 to 40 tons, and the bar failed, this in every case being where indented bars were used of a small size in comparison to the length embedded in the concrete. The average tensile breaking strength of the metal being 37.12 tons per sq. in. or about the same as an average obtained from makers' pamphlets, the range being from 38 to 34 tons, our maximum therefore being about 2 tons below that claimed by the makers. This is slightly lower than that given by the makers, who give in their catalogues a typical test of 39.7 tons per sq. in. with maximum above mentioned, but is above what is required by the Public Works Department standard specifications, which speci-

fy that the tensile strength shall be from 27 to 31 tons per sq. in. The figures for ultimate strength given in Buel & Hill and Marsh & Dunn are respectively 27.68 and 26.78 tons.

The results obtained from these tests are from my point of view disappointing in regard to round bars. I fully anticipated that better results would have been obtained from those than from the square bars. In fact, our experience here is different from all other experimenters, and I can in no way account for the comparatively low results obtained from our round bars. The figures as given work out as a fair average that the frictional resistance and adhesive strength between the concrete and the bars is:

For round bars, 170 lbs. per sq. in.

For square bars, 181.5 lbs. per sq. in.

For indented bars, 453.6 lbs. per sq. in.

In the experiments conducted by Professor Warren already mentioned, the average resistance to withdrawal for a $\frac{5}{8}$ in. plain steel Bessemer bar, with the natural skin on, embedded in concrete, is about 198 lbs. per sq in., against an average of 175.5 lbs. per sq. in. for the round and square bars experimented upon by us, and in both his and our experiments some of the individual cases agree very closely.

The above results fall considerably short of those given in several of the text books. Buel and Hill state 570 to 750 lbs. per sq. in., and Marsh and Dunn referring to Messrs. Bauchinger and de Joly give 570 to 710 lbs. per sq. in., and others place such resistance at over 400 lbs. per sq. in.

The maximum actual results of our tests on plain bars give 224 lbs. for round and 217 lbs. for square bars, though the poor behaviour of several of the round specimens makes the average below that of the square bars.

With regard to the indented bars. our test showed a maximum resistance of 828 lbs. per sq. in. for one example in which instance the bar failed. Marsh and Dunn quote as a maximum and an average for this class of bar 639 and 484 lbs. per sq. in. respectively, so that for plain bars our experiments go to show that the results given in text books are higher than we are likely to get in actual working practice when using ordinary commercial concrete, but our results for indented bars show a higher maximum of 828 and a slightly lower average of 446 lbs. per sq. in.

These figures, as already seen, are much above results obtained from the tests carried out where the maximum adhesion was 828 lbs. In three only the results did go more than 500 lbs., and in four cases over

400; therefore, it appears from our experience with ordinary commercial concrete that the results given in the text books and makers' pamphlets are higher than we can expect in actual working practice.

Interesting figures were obtained from the diagrams taken after the first rupture point had been reached, the lateral friction between the loose bar and the concrete being fairly considerable. For round bars this was found to be 55 per cent., for square 40 per cent., for indented 18 per cent. of the load required to cause rupture to take place. The figures for the round bars would naturally appear high when the low rupture point is taken into consideration, and the square bar is apparently a fair average.

With regard to the indented bar, the low adhesive friction after movement had taken place can be accounted for, I think, by the shearing effect of the indents when failure was taking place. This left a fairly large aperture around the bar, and the concrete shearing or giving way made the friction much lower than a plain bar would show

Professor Hatt's experiments show that for smooth, round bars the lateral friction after movement was 60 per cent. to 70 per cent. of the adhesion. The figures obtained by our experiments in this direction, though lower than the above, seem to be in line with the average of previous results. There has been a great deal of discussion as to the advantages of deformed or irregular shaped bars for reinforcing purposes and the experiments made certainly bear out the statement that for obtaining the best results for adhesion between concrete and steel the indented and bars of a similar type possess undoubted advantages, and not only does this apply in my opinion to test purposes, but would be of great benefit as the age of the concrete work increases.

I may mention that I know of one instance where a bridge was put over a railway with plain reinforcements, and I understand that, owing to the vibration, considerable movement took place between the reinforcement and the concrete Other instances are on record also of failures of floors due to loose adhesion even after the structure has supported a considerable load for many years—that as perfect a union as possible between the reinforcement and the concrete is desirable there can be no doubt.

Our experiments also proved that the adhesion is greater with rough surfaces than with plain. Probably the low results obtained from our tests may be accounted for by the large size of the stone used in the concrete, and in this direction I feel that there is no question that for the purposes of reinforced concrete the best results will be obtained when metal not exceeding ¾ in. gauge is used. This was the class of metal used by Professor Warren, and many of the results obtained by

previous experiments were based on figures obtained from what may practcalliy be termed cement mortar, in which not much matrix was used.

I put up herewith tables showing briefly the results obtained, and also the diagrams from the testing room at Midland Junction, the date of manufacture of the concrete blocks, weight of same and other information.

It seems possible to deduce formulæ applicable to each type of bar for the purpose of obtaining the effective length of bar to be embedded to obtain the fullest advantage of the tensile strength of the reinforcement. This may be stated as:—

$$L = \frac{78{,}400 \times AR}{F \times P}$$ where L = effective depth in inches of bar embedded.

78,400 = tensile strength of steel in pounds.
AR = area of particular section of steel.
P = perimeter of side.
F = value of frictional resistance of section where F = 170 for round bars, 182 for square bars, 453 for indented bars.

These figures can, of course, be only taken as an approximation but will, I think, be near enough for practical purposes.

I did not anticipate such a large difference in the adhesive strength between the plain and indented bars, the results having proved conclusively to my mind that the indented bars or those of a similar type have a decided advantage over the plain, round or square rods for reinforcement purposes.

Tests of Indented, Square and Round Steel Bars in Concrete Blocks.

No. of blocks, 30.
Actual weight of blocks, 2,929.93 lbs.
Total cubic feet in blocks, 18.4726 cub. ft.
Computed weight of steel in blocks, 105.1903 lbs.
Weight of concrete less steel, 2,824.7197 lbs.
Weight of concrete less steel per cub. ft., 153 lbs.
Percentage of steel bars to concrete by weight, .57.

TEST OF PATENT INDENTED STEEL BARS.

Spec. No.	Nominal Particulars of Specimen. Concrete. Length ins.	Concrete. Sq in ins.	Style.	Size ins.	Size of Bar by micrometer. ins.	Nominal surface contact of bar in sq. ins.	Load. Max. Actual Tons.	Load. Per sq. in. of Bar.	Elongation in 8in. Actual inches.	Elongation in 8in. Per cent.	Surface friction in lbs. per sq. inch.	Remarks.
1	8	6	Round	$\frac{1}{4}$	.318	8	.25	3.29	—	—	69 min.	Bar drew out
2	12	6	,,	$\frac{1}{4}$	.318	12	.78	10.26	—	—	145	,, ,,
3	16	6	,,	$\frac{1}{4}$	.318	16	1.6	21.05	—	—	224max.	,, ,,
4	12	6	,,	$\frac{3}{8}$	.385	14	1.05	9.54	—	—	168	,, ,,
5	16	6	,,	$\frac{3}{8}$	.385	18	.94	8.54	—	—	116	,, ,,
6	20	6	,,	$\frac{3}{8}$	.385	23	2.11	19.18	—	—	203	,, ,,
7	30	8	,,	$\frac{7}{8}$	.879	82	6.4	10.64	—	—	174	,, ,,
8	36	8	,,	$\frac{7}{8}$	.874	98	7.56	12.57	—	—	172	,, ,,
9	30	8	,,	$1\frac{1}{8}$	1.129	106	10.7	10.76	—	—	224	,, ,,
10	36	8	,,	$1\frac{1}{8}$	1.129	127	11.45	11.51	—	—	201	,,
											Average 169.6	
11	8	6	Square	$\frac{1}{4}$	.263	8	.73	10.58	—	—	203	,, ,,
12	12	6	,,	$\frac{1}{4}$	.263	12	1.04	15.07	—	—	192	,, ,,
13	16	6	,,	$\frac{1}{4}$	.263	16	.65	9.42	—	—	89 min.	,, ,,
14	18	8	,,	$\frac{1}{2}$	.504	36	3.52	14.08	.937	11.7	217 max.	,, ,,
15	24	8	,,	$\frac{1}{2}$	.504	48	3.41	13.64	—	—	159	,, ,,
16	30	8	,,	$\frac{3}{4}$	.759	90	8.7	15.48	—	—	215	,, ,,
17	30	8	,,	1	1.013	120	10.83	10.83	—	—	201	,, ,,
18	36	8	,,	1	1.013	144	11.38	11.38	—	—	176	,, ,,
											Average 181.5	
19	8	6	Indented	$\frac{1}{4}$	—	8	1.01	16.16	—	—	282 min.	,, ,, concrete failed longitudinally.
20	12	6	,,	$\frac{1}{4}$	—	12	2.35	37.6	.875	10.9	439	Bar failed
21	16	6	,,	$\frac{1}{4}$	—	16	2.35	37.6	.875	10.9	327	,,
22	8	6	,,	5–16	—	10	3.7	38.14	1.25	15.6	828 max.	,,
23	12	6	,,	5–16	—	15	3.42	35.25	—	—	510	Bar drew out, concrete failed longitudinally.
24	16	6	,,	$\frac{3}{8}$	—	20	3.72	38.35	1.218	15.2	416	Bar failed
25	18	8	,,	$\frac{1}{2}$	—	36	8.48	33.92	1.218	15.2	526	,,
26	24	8	,,	$\frac{1}{2}$	—	48	8.3	33.2	—	—	385	Bar drew out
27	18	8	,,	$\frac{3}{4}$	—	54	13.0	23.13	.187	2.3	537	,, ,, concrete failed longitudinally
28	24	8	,,	$\frac{3}{4}$	—	72	13.55	24.11	.25	3.1	421	Bar drew out; concrete failed longitudinally
29	18	8	,,	1	—	72	13.18	13.18	—	—	409	Bar drew out; concrete failed longitudinally
30	24	8	,,	1	—	96	15.6	13.18	—	—	362	Bar drew out; concrete failed longitudinally
											Average 453.6	

MIDLAND JUNCTION WORKSHOPS MACHINERY.

By E. S. Hume.

It is not my intention this evening to describe a modern engineering works with its centralised power-generating station, or to trace through the media of steam, electricity, water or air, the ultimate expression of the conveyed energy in the work of the steam hammer, the lathe, the hydraulic press, the foundry blast or the pneumatic machine tool. The members of this Institution have seen for themselves, so far as the comparatively limited time of an afternoon would permit, most of the equipment of the railway workshops at Midland Junction. It is some of the features of that equipment and the methods of work that I propose to make the subject of my notes this evening, the special interest attaching to those chosen being that they have been either conceived, added to or altered in the course of the author's ten and a half years' connection with the Locomotive Branch of the Western Australian Government Railways. I have much pleasure in acknowledging the courtesy and kindness of the Commissioner of Railways, which enables me to bring before you the information contained in this paper on "Workshops, Appliances and Methods."

Boiler Tube Rumbler.

To elucidate the points it will be necessary in many cases to refer to the methods previously in vogue. Thus, when it is noted that boiler tubes are now cleaned from scale by striking and rubbing against each other as the rumbler in which they are enclosed is rotated, one is apt to forget that in 1900 it was the practice to place the tubes in a lead bath containing a strong sulphuric acid solution, and after leaving them there for from twelve to twenty-four hours, it was the work of two men, wearing india-rubber gloves and boots, to scrub off the loosened scale. This occupation was considered unhealthy and higher pay than was warranted by the value of the work performed was demanded on account of time lost. The complaints became constant, and the matter of establishing a rumbler was brought before the then Chief Mechanical Engineer by myself. It was with some difficulty that consent was obtained to the scheme, as it was feared that the noise of the rumbler would be a source of annoyance from its situation close to the Chief's room, and it was only on my undertaking that the operation would be noiseless that the opposition was withdrawn. It might be mentioned in passing that the machine was erected and at work for a week before its existence was known to Mr. Rotheram, so that the claim of comparative noiselessness might be considered to be fairly well established. The absence of noise was, of course, due to the ends of the barrel being hermetically sealed.

Drawing No. 1,971 shows the rumbler as designed. For the original one an old locomotive boiler barrel was used ; the inside was lagged with soft wood, the ends closed watertight with plates, one end having a water-tight door for the insertion and removal of the tubes, and through which the " charge " of water and sand was poured. So as to leave this end free and get-at-able the barrel had fastened to it an old locomotive tyre turned flat on the tread which rested on rollers. On the other end of the barrel a gudgeon was rivetted. This ran in a plummer block and was connected to the belt drive by suitable spur gearing, the rate of revolution of the rumbler being sixteen per minute. The original barrel was in use nine years and was replaced last December.

To clean a set of tubes by the old method took two men two days. By the new method the work can be done in thirty minutes, and the man attending to the rumbler can do other work during a portion of the time. Care is taken not to continue the rumbling after the scale is removed.

Standard Fusible Plug.

All users of steam power are seized with the necessity of having an effective tell-tale to give warning when the water in the boiler becomes low, and to none is it of more vital importance than to the locomotive engineer. The exigencies of road work at times call forth all the resources of even the best of drivers, and when an error of judgment occurs the results might be truly disastrous were it not for the provision of a reliable fusible plug. Up to 1900 the plug which was recognised as the standard on our railways was in accordance with Drawing No. 1,972. The ⅝ in. tapped hole in the centre was filled with lead and the plug was then screwed into the centre of the firebox crown plate as per Drawing No. 1,973. When the boiler through any cause became short of water, the lead certainly fused and gave the alarm, but the action was so tardy that before the fire could be withdrawn or damped in many cases very extensive damage through overheating had been done to the firebox. One typical case occurred during 1900, when the crown sheet, the stays, the tubeplate, and three rows of tubes in a locomotive boiler were destroyed.

The present standard fusible plug was introduced by the late Chief Mechanical Engineer, Mr. Rotheram, and is also shown on Drawing No. 1,972. The metal liner is an alloy composed of 95.24 per cent. of lead and 4.7 per cent. of antimony, and fails under test at a temperature of 500° Fahr. with steam at 200 lbs. Two plugs are screwed into the crown sheet as shown, so that should any part be bare when taking curves or grades, the metal in the plug subjected to the greatest temperature would fail and the brass cone would drop, leaving an opening sufficient to permit the steam to damp the fire. Sometimes by an alteration in the position of the locomotive the water would again flow over the opening and assist in putting the fire out. As a general rule the brass cone is discovered

uninjured amongst the ashes. So effective have these plugs proved that since their adoption no instance of damage to boilers or men has occurred from shortage of water. The ready response of these plugs to neglect or carelessness on the part of the engineman led to an assertion by the Drivers' Union that it was possible for the plug to drop without there being an actual shortage of water. It was claimed that the temperature attained in the boiler at high pressure would soften the fusible metal to such an extent as to permit the brass cone being forced through, or such action would take place through the liner being reduced in thickness. Experiments were carried out which demonstrated that the claims of the Union were groundless.

In order, however, to prevent any undue reduction of the liner, monthly inspections are made of all fusible plugs, and the result recorded in a book kept for that purpose, the liners being renewed as often as may be found necessary. Although in no case have the fusible liners been reduced to such an extent as to cause a failure from that cause between monthly examinations, still, waters of the composition shown in analysis sheet at end as tests Nos. 1,314 and 1,494, do have an effect on the fusible alloy, this action being due to the alkaline carbonates, while water with the constituents shown as test No. 2,745 had little or no effect. This is plainly shown in photo marked " A." The plug liner taken from the Kalgoorlie boiler has been subjected to the action of water similar in composition to test No. 2,745, and shows practically no loss, while the wasting effect of the Bunbury and Perth bore waters on the liners (tests Nos. 1,314 and 1,494) is very apparent. At the time the new standard plug was introduced the punishment inflicted on drivers who dropped a fusible plug was very severe, being somewhat commensurate with the amount of damage which usually accompanied a failure of the old type plug, but owing to the reduction of the risk when using the new standard plug and the absence of damage to the boiler, it has been found possible and politic to inflict a nominal penalty only for the carelessness displayed in running short of water.

One feature in connection with these plugs which goes to point out the necessity of using standard gauges in the manufacture of such material, was that it was discovered that although made to drawing,an alteration in the square core might increase the length of the liner barrel so that the brass plug would not fall through when the alloy melted. To overcome this, male and female gauges were made, by the use of which the plug and the chamber are kept true to size before issue.

Boiler Tube Ferrules.

Another detail connected with locomotive boilers in which an important improvement has been effected is the manufacture of boiler tube ferrules. In 1900 the method in force was to manufacture the ferrules as follows :—

Iron, 5¾ in. x 1⅜ in. x 3-16 in. was cut off and welded by a blacksmith and striker at the rate of 200 ferrules in the rough per day. These were then taken to the lathe and turned to various sizes, the average number so turned being 80 per day. Although the above numbers seem very small, they represent all that was possible to put out by the method described, and at the same time the ferrule so made was by no means satisfactory, either in form or in strength, and frequently failed at the weld. An essay was made to increase the output by means of butt welding the ferrule under a pneumatic hammer. This resulted in the output per blacksmith and striker being increased to 300 per day. The ferrules of course had to be turned in a similar manner as before, and the output from the lathe remained the same. I was far from satisfied with the result attained, and during 1903 issued instructions that experiments were to be carried out to see to what extent solid drawn steel tubes could be expanded without fracture. It was found that the operation could be continued successfully until a piece of the original size could be passed through the interior of the expanded tube. It happened that during that year a Herbert automatic stud lathe was installed in the workshops. With the assistance and co-operation of the workshops manager and the foreman turner, a jig was devised in accordance with drawing No. 1,974. With the use of this attachment it was only necessary to insert a tube into the Herbert lathe when it would be advanced the required distance to enable the proper length of ferrule to be parted off automatically and the following one rounded off at the end simultaneously. By this means the ferrule lengths could be parted off at the rate of 1,000 per day of 8 hours, the machine being operated by a youth. The expanding and tapering of the ferrule was the next step, and in order that this could be done in an accurate and methodical manner, the author invented a jig as shown in drawing No. 1,975. The taper of the mandril used is ⅛ in. in 5 in. or 1 in 40. The jig is attached to an old type vertical slotting machine, and the various sizes of the ferrules are regulated by altering the stroke of the slotter, which forces the mandril a greater or lesser distance through the ferrule. The completed ferrule is removed from the mandril on the ascending stroke of the slotting machine by coming into contact with the bottom of the bracket shown. The number of ferrules which can be tapered by this process is limited only by the rate of drive of the machine, given an operator possessed of the requisite skill and energy. The average number of ferrules tapered per day of 8 hours is 4,800.

Besides the increased output and reduction in cost, one great advantage obtained by the above process is that the ferrules are perfectly uniform, of minimum thickness, and true at point and face, enabling them to be inserted and driven home in a snug and workmanlike manner, thereby reducing the number of leaking tubes and distorted tube sheets.

Alteration to Wheel Lathe.

The introduction of high speed tool steel made it necessary when ordering machinery for the equipment of the Midland Junction workshops, to specify that all the machines in which it was possible to use that class of steel were to be manufactured of such design and strength as to enable full advantage to be obtained from the use of tools manufactured from that class of materials. By the time the machines were erected in 1904, however, it was discovered that the improved quality of high speed tool steel surpassed the capabilities of the wheel lathes which had been obtained. The author then decided to alter one of these lathes to make it more in accordance with the increased progression and heavier cut that the cutting tool was capable of withstanding without injury. This was done by increasing the steps on the driving coned pulley to double their original width, and in place of the 4 in. driving belt an 8 in. double English leather belt was adopted (see drawing No. 1,976). In addition to the ordinary wear and tear of the wheel tyres these wheel lathes have to deal in some cases with wheels which have been badly skidded in service, and members will readily understand that the "hardness" of a flat which has been skidded for a considerable distance over a cold rail is something quite beyond what is ordinarily understood by that term. In order, therefore, to prevent jarring and chattering of the tool through the greater power exerted and speed run, the centres of the lathe were shortened up as shown in the above drawing, and eight drivers manufactured from tool steel and serrated as shown were attached to the lathe heads to take up the vibration and withstand the severe torsional strain. The shapes of the tools used are shown in drawing No. 1,977. In carrying out the work of alteration I have again to acknowledge the hearty assistance and co-operation of the workshops manager and the foreman turner. Before the lathe was altered it was the work of one day to turn up one pair of locomotive driving tyres 4 ft. 6 in. in diameter. With the altered lathe it has been possible to turn up three pairs of the same class of wheel. An even greater difference is observable when dealing with carriage and wagon wheels. As many as ten pairs have been turned out in one day by an apprentice, whereas the maximum output by the old process was two pairs per day. Another result of the alteration is that fewer lathes are required for the wheel work at Midland Junction, and it has been found possible to set apart wheel lathes for special work such as turning cylinder bushes, vacuum cylinders, pistons, and piston rings; and also to send wheel lathes to Kalgoorlie and Geraldton running sheds, and thus save the expense of forwarding a number of wheels from those districts to the Midland Junction workshops for turning. Photo marked "D" shows the comparative size of the turnings before and after the alteration of the lathe, and this photo, together with those marked "B" and "C," will convey to members an adequate idea of the difference in the work accomplished.

Oil Saving, Blending, Filtering, and Waste Saving Plant.

The desirability of recovering and re-using the oil contained in worn-out lubricator pads, oily waste, etc., has always interested me, and during the latter part of 1903 I commenced enquiries concerning the existence of suitable machinery which would recover the oil from the waste and enable both to be re-used. Although at first no information could be obtained concerning such machinery, orders were issued to store all refuse, oil and dirty waste, so that failing the obtaining of a machine from outside, a machine would be designed and installed by ourselves. In fact an experimental machine was made and gave encouraging results. In the year 1905, however, in reply to a letter sent by me in the previous June, word was received that a machine of the type required had been introduced into the market. The necessary authority was obtained, and after waiting some time the machine was erected at the Midland Junction workshops in July, 1907. Photo marked "E" shows this installation, which has proved altogether successful and has done all that it has been asked to do. The cost of working is very low, as the fuel used in the steam boiler is waste from the woodworking mill. The machine is an enclosed turbine, and the steam which rotates it also assists in the action of extracting the oil from the waste. A charge of the oily waste is dumped in at the top of the machine, steam is turned on, the oil flows out of the pipes provided, and when it has run a sufficient time the machine is stopped and the cleansed waste lifted out and a fresh charge of oily waste put in. The waste is recovered in a wet condition from the oil saving machine, and while in colder climates it is necessary to have it subjected to artificial heat in drying rooms before it can be made fit for use, in this climate it has been found unnecessary, as the heat of the summer sun is sufficient to thoroughly dry it. The waste is put on a platform about 2 ft. high, constructed of old iron plates, and turned over twice daily. When it is thoroughly dry it is put through a teasing machine and is then fit for use. This recovered waste is sent to the running sheds and used with new waste in the proportion of 2 to 1. The old worsted lubricators from which the oil is extracted are also dried and teased, and used for packing axle boxes which have an unnecessarily deep oil well.

While this machine was being obtained the matter of blending our own oils was taken in hand owing to the trouble that had been experienced with the quality of oil supplied for use in the lubrication of locomotives, carriages, and wagons. The blending plant as shown in drawing 1,978 was installed at the Midland Junction workshops, and the oil as received from stores is tested and blended and made suitable for the work to be performed, having due regard to the difference in atmospheric temperature of winter and summer. I would like to take this opportunity of acknowledging the valuable and full information received from Mr. T. H. Woodroffe, the Chief Mechanical Engineer of the Victorian Railways, concerning

the oil blending and filtering plant in use at Melbourne, which was of great assistance when arranging our own installation. From the drawings and the information given it will be judged that the plant at Midland Junction is very complete. The result is that the recovered oil can be purified. Oil is also blended and tested in such a manner before issue to running branch that there has been a very considerable reduction in the " hot box " trouble, and a consequent removal of a number of vexatious delays which the general public were subjected to at one time when unsuitable oil was being supplied and used. This was especially the case during the summer months on the goldfields, where the combined influence of the sun and dust is such that the use of only the best class of oil is an indispensable condition to satisfactory running.

The effect on expenditure of the special attention which has been given to this subject is shown by the following :—In 1903, oil, tallow, waste, etc., for locomotives, cost £11,070 ; in 1909 this cost was reduced to £5,312—a direct saving of £5,758. A corresponding decrease was made in the cost of similar material for carriages and wagons, while at the same time the work done increased by 3½ million passenger journeys and 230,000 tons of goods hauled.

Locomotive Weighing Machines.

The loads permissible on the Western Australian Government Railways on rails weighing 60 lbs. to the yard is 6 tons per wheel, and on rails weighing 45 lbs. it is 4 tons 10 cwts. per wheel. It is, of course, very desirable that each wheel of a locomotive bears as nearly as possible the load for which it was designed when the locomotive is in full working trim with water in the boiler, and water and coal in tanks and tender.

When the machinery was ordered for the Midland Junction workshops it was considered that the weighing machines shown in photos referred to at the end of this section were the most suitable for the purpose required, the makers being the Fairbanks Company, of St. Johnsbury, Vermont, U.S.A. The original intention was to stand the weighing machines on the middle road of the erecting shop, and after lifting the locomotives high enough by means of two thirty-ton electric cranes, to roll the weighing machines under each wheel so that the centre of the machine should be in line with the centre of the wheel and axle, and then to make any necessary adjustment of the springs as indicated by the weight shown on the weighing machine scale. When the weighing was done it would have been necessary to lift the machines out of the road and put them to one side, so that the centre road could be utilised. In considering this phase of the matter and having in view the limited accommodation provided in the erecting shop and also the objectionable feature of axles resting on the axle box keeps whilst the locomotive was suspended by the crane, instead of the axles taking the weight of the locomotives on the finished surface of the axle

brasses, the author decided to place the weighing machines underground and run the locomotives at ground level on to the machines. This idea was carried out with the assistance of the then Chief Draftsman, Mr. G. A. Julius. Drawing No. 1,979 gives a very good outline of how the idea was given effect to. The locomotive is run on to girders over the weighing machines, which stand on rails in the pit under the locomotive. The machines are moved to the proper positions, and the girders are then lowered until the wheels rest on the weighing machines. This movement is effected by means of screw jacks operated by spur gearing driven by a 7 h.p. electric motor, the time occupied in lowering on to the weighing machine being three minutes, the same time being taken to elevate to rail level again. The adjusting of the springs can be expeditiously and easily carried out owing to the adequate pit room, and in addition to this the locomotive can be moved forward and backward in the shed by means of the same electric motor as is used for the lowering and raising of the girders operating a capstan around which a rope is placed, one end being attached to the leading draw bar when setting the valves in forward gear, another rope being in readiness to be brought into operation with its end passed through a snatch block at the far end of the weighing pit, then fastened to the intermediate draw bar for the back gear setting.

The weighbridge is also used for finding the centre of gravity of our rolling stock. This is done by raising the locomotive or vehicle to be tested about 10 to 12 inches, then lowering one side direct on to the scales and on the other side inserting a wooden block about 10 inches high between the wheels and scales, thus tipping the vehicle to that extent and moving the centre of gravity to one side; then by the difference of weights obtained on either side the height of the centre of gravity is calculated. Although this method of weighing locomotives has been in operation since November, 1906, no repairs or alterations have been found necessary and the method of employing the machines and equipment has proved to be expeditious and economical.

Photos marked "F," "G," "H," and "I" illustrate the installation and method of use.

Standard 1904 Axle Box.

Previous to 1904 it was very common to have wagon axle boxes broken by the lateral movement allowed by wear of brasses or by rough shunting. The failure mostly occurred at the back, where the dust shield is inserted, and necessitated the replacement of the whole of the axle box—a costly proceeding. In order to render these replacements unnecessary the author invented a separate part to enclose the dust shield, which can be easily attached or detached from the rest of the axle box, being held in place by a split pin, and is renewable at very small cost. For particulars see drawing "L" 1. In other details the type of box adopted in 1904

generally closely resembles the axle box supplied with the American trucks and locomotive tenders, it only being necessary to alter a few parts in order to make them conform with our stock, and get the best results from our bearing brasses and methods of lubrication. The types of axle boxes previously in use—and in some cases still in use—are shown on drawings A to L1 (12 types in all). Following on the introduction of this standard axle box, it was decided to line the axle box brasses with white metal. This enabled us to use a cheaper kind of brass, which it was the custom to sell previously by auction as scrap, while at the same time special bronze was purchased and used in the manufacture of the axle box brasses. The cost per brass has been appreciably reduced. The adoption of the 1904 axle box and the white metalling of the brasses has worked conjointly in increasing the life of the brasses to eight or nine times that of the older type, and has practically removed from passenger trains the nightmare of delays through overheated axle journals.

Hydraulic Tools.

An interesting example of the application of hydraulic power in turning out work which up to that time had been done by the blacksmith, was put into operation in 1902. At that time the work in the blacksmiths' and boiler shops at Fremantle had increased to such an extent that a night shift was necessary to cope with it. It has always been my experience that night work is satisfactory to neither employer nor employee, and permission was asked for to erect a hydraulic plant which had been stored at the Government Stores at North Fremantle for some time. It was necessary to urge this request with some persistency, as doubts as to the utility of the scheme had to be overcome. However, the pumps, accumulator, and press were erected, and by the use of suitable dies the advantages of the plant were very soon demonstrated. To take a single instance of an everyday requirement, the new style wagon buffing plates shown in drawing No. 1,980 cost only one-third to manufacture compared with the old method also shown. The old style plate had pieces welded in at the corners, but by the new method steel was used instead of iron and an equally satisfactory job turned out. The general gain in the amount of work turned out from the use of the hydraulic plant brought about the abolition of the night shift in four months' time. The plant also enabled work to be done locally which was previously imported in a manufactured condition.

Construction of Locomotive Boilers.

One of the advantages of removal of the workshops to Midland Junction is demonstrated by the fact that it is now possible to make locomotive boilers at less cost than they can be imported for. This is due principally to the modern equipment which is available, consisting of hydraulic and pneumatic machinery, heavy plate rolls, cold saws, plate edge planers,

as well as being able to re-use many of the original mountings and fittings which had not worn out at the same rate as the boilers themselves. A considerable advantage is also gained by the careful fitting of the parts together, and the better class of work carried out under the personal supervision of railway officers who are not only responsible for the manufacture of the boilers but also for their maintenance afterwards.

Owing to the searching nature of the water available for use in boilers here, the ordinarily fitted and rivetted boiler did not prove anything like as satisfactory as the boilers manufactured locally. All the material put into the locally manufactured boilers is carefully tested and inspected, and its behaviour can be watched with a view to discontinuing the use of any particular material if found unsatisfactory. In this connection the result of experiments which have been conducted on different material with a view to ascertaining their tendency towards electrolytic or corrosive action, could well form the subject of a separate paper if the members would consider such acceptable.

Construction of Carriages and Wagons.

With the provision of greater accommodation and increased appliances when the workshops were removed to Midland Junction it became possible to undertake the construction of carriages and wagons. In dealing with the latter it was considered by the author to be a great mistake to continue the construction of iron framed four wheeled trucks when such suitable timber as tuart and wandoo could be obtained in the State ; therefore, when instructions were received to construct 500 four-wheel trucks a supply of tuart timber was obtained and put into the wagons. At the same time axles of standard design were ordered, so that wheels which originally had key seats (and which had been removed from service owing to their axles being too weak for the work required) were bored out, the boss being turned and undercut and banded as shown in drawing No. 1,981, and used in connection with the construction of the trucks. A considerable quantity of other material which was held in the workshops as " dead " stores was also worked up and made suitable for the trucks.

During the past six years the whole of the new cars added to the stock have been manufactured locally, either in the Midland Junction workshops or by contract at Rocky Bay. One great advantage of the local manufacture is that cars can be manufactured all in one piece, instead of in sections, which was necessary when they had to be shipped. Local manufacture also permits a greater range of constructive design. Here as with the wagon stock money is saved by doing the work in the State.

Coaling Appliances.

The handling of coal at locomotive depots until within the last five or six years was a comparatively expensive arrangement. At the largest

depots ten fuelmen were continuously employed, the next sized depots employing six, and these forces had to be augmented by casual hands when larger quantities of coal than usual arrived in trucks. The coal was shovelled by hand from trucks on to coal stages, the decks of which were on a level with the floors of the trucks. When the coal to be dealt with exceeded the capacity of the stage, the reserve stock was unloaded on to a sleeper floor at ground level. On both the stage and the reserve dump walls had to be built of the larger pieces of coal to prevent it falling on to the lines alongside. The method of coaling the tenders was by coal baskets, filled by hand and lifted on to the tenders and emptied. When it became necessary to use the reserve stock it meant double handling. Photo marked " J " illustrates this system of coal storage.

At Northam and Kalgoorlie overhead stages have been established which somewhat reduced the cost of handling the coal. These are rather extensive erections, part being shown in photo marked " K." The trucks are run up the ramp and emptied and the coal dropped on to the deck of the stage. Steel bogie coal hopper trucks were imported for the work of conveying the coal from mine or boat to the stage. They are very suitable for the purpose for which they were designed, and the dumping arrangement is easily and economically operated. For use on the stage itself small hand tip trucks were manufactured locally. The coal is shovelled into these small trucks, wheeled to the edge of the stage and tipped into the tender, the height of the stage being such that there is head room enough to perform this operation with a minimum of trimming by hand on the tender. By the overhead system just explained the number of fuelmen permanently employed does not exceed four, that number being necessary as locomotives have to be coaled any time during the twenty-four hours. Casual labor has also to be frequently employed to unload as coal is supplied in high-sided trucks when the hopper trucks are not available. This especially occurs when a large shipment of coal has been received at Fremantle.

With the transfer of the workshops from Fremantle and Albany to Midland Junction, and the handing over of the wharf management to the Harbor Trust, a number of steam cranes ranging in power from three to ten tons lifting capacity were liberated. The author decided to use these cranes for handling coal by means of a grab. Experiments were carried out at Perth with a Priestman grab, which was kindly loaned by the Engineer-in-Chief (Mr. Thompson). This proved so successful that the jib of a ten ton steam travelling crane was lengthened to fifty feet and an overhead bin was erected at Midland Junction by the Ways and Works Branch of the Railway Department, then controlled by Mr. Dartnall. The lengthening of the jib enabled the coal to be lifted out of a truck by means of a grab, and either stacked it on a sleeper floor or lifted direct over the bin and dumped there. At Midland Junction two bins were constructed, one for Collie coal and the other for Newcastle coal. The

reason for keeping the bins separate is that in the winter months a much large proportion of Collie coal is used than is permissible during the harvest months, and in coaling the tenders the proper proportions can by this means be accurately regulated. The coal is delivered from the bins by means of shoots which are so balanced as to be very easily operated. The locomotive is run under the shoot and the coal discharged direct into the centre of the tender. When operating the shoots the coal is automatically damped by a water jet which not only prevents excessive dust and keeps the locomotives clean when running into the tender, but avoids a considerable waste of the smaller particles of coal. Needless to say this damping of the coal is much appreciated by the men who attend to the coaling. Five tons of coal can be put on to a locomotive tender and levelled off ready for traffic in five minutes, as against thirty to forty minutes by the old method of handling per basket. Photo marked " L " shows the coal bin, reserve heap, crane and grab.

In order to use the smaller sized cranes another type of coal bin and stage was designed, and one is now in use at Fremantle as per photo marked " M." With the equipment at Midland Junction one hundred tons per shift of eight hours can readily be handled, two men only being engaged. This enables trucks to be quickly released and when the bins are filled the coal can be put on to the reserve heap, from which it can be again lifted very quickly when there is a shortage of coal in trucks to be dealt with. Prior to the grab and bin being used the number of men regularly engaged in coaling was six. Of the two men now necessary, one operates the crane, the other breaks the large coal, adjusts the grab into the truck and sees to the getting of trucks into position. There is no necessity to work more than the one shift at this depot as the coal which is placed into the bins during that shift is sufficient for the twenty-four hours. Another great advantage of this system is that when the engines come off traffic they can be run under the shoots and coaled without loss of time, and can be stabled with their own steam before the pressure falls to any great extend instead of having to be hauled around dead. Again, at Fremantle the locomotives engaged on the passenger suburban service which have a comparatively limited bunker accommodation can run into the locomotive department, take coal, and be back again on their trains within a quarter of an hour. At Midland Junction this procedure also applies to the shunting locomotives. These plants have been in operation for several years and have so far worked without a hitch.

At Perth the complete system is not yet in force. The coal is handled by a grap direct from the truck into the tender, and when a larger amount of coal is at hand under load than is required for coaling tenders it is unloaded on to the stage or on to a reserve dump to be lifted from there on to the tenders by means of the grab. Three shifts are worked at Perth, the number of men employed during the twenty-four hours being

six. This means the saving of four men's wages, but it is hoped that it will be possible very soon to have a complete system established, including the overhead bin and this will effect a further considerable saving both in wages and in the time of coaling locomotives. At Southern Cross a bin similar to that at Fremantle is now in course of erection.

GRAVITY DUMP FOR STORAGE OF COAL.

It is necessary to have a reserve stock of hard coal on hand and up to 1908 the method of dealing with this coal was to unload it from highsided trucks on to a sleeper floor, which necessitated a large amount of re-shovelling to trim it into heaps of such height as would permit of say thirty thousand tons being stored without undue expenditure of room and rail track. From these heaps the coal had to be re-loaded by hand into trucks despatched to the various locomotive depots. The coal was stacked at North Fremantle as it was necessary to release the trucks as quickly as possible. For obvious reasons it was undesirable to have a large stock of coal available at North Fremantle, and as the Comptroller of Stores was located at Midland Junction no direct supervision could be exercised over the coal stocks. The author, therefore, conceived the idea of an overhead dump, as shown in photo marked " N." The detail drawing and the erection of the dump at Midland Junction was carried out by the staff of the Existing Lines Branch, under the control of the Chief Engineer of Existing Lines (Mr. Light). At this dump ten thousand tons of hard coal has been stored, and should it be necessary double that quantity can be dealt with, but it has been decided to keep the stock down to seventeen thousand tons, as with the reserves usually held at the various depots and the quantity in transit, the amount quoted is considered sufficient to be stored at the one place. When it is necessary to draw upon this reserve stock, the coal is lifted from the dump by means of the grab crane standing on one line and loaded into trucks standing on the second line. Either hopper or ordinary high-sided trucks can be loaded by this means, so that both the high level and the ordinary stages can be supplied. The system has worked admirably since its installation. Hopper trucks are loaded at ship's side at Fremantle and run directly on to the pile track at Midland Junction, the doors are opened the coal falls through on to, the dump, and without loss of time the trucks are ready to be returned to the ship for another load. When the coal heap rises towards the floor of the overhead track it is trimmed back by the use of the grab, so that the next lot of coal arriving drops into the hole so prepared. The re-loading into trucks is equally successful.

SUBSTITUTION OF HARDWOOD FOR CAPPED SOFTWOOD ON TOP OF TRUCK SHEATHING.

Before concluding my paper, which has dealt with some fairly large issues, I would like to give an instance where the alteration of a small

detail in the construction of trucks has had a very far reaching effect. Members will have noticed, at any rate until recently, that the top board of most of our open trucks was capped with a strip of iron held down by screws. The practice of unloading timber by cranes and derricks caused a good deal of trouble and expense through this capping being torn off or sprung, with the result that the top board was often destroyed, and in any case the capping had to be renewed. Not only was the capping torn off, but the high summer temperature experienced here caused the screws or bolts which hold down the capping to become loosened and rendered the removal of the capping and damage to the top board very easy when rough methods of handling goods were employed, as is sometimes the case —even on the Western Australian Government Railways. This constant renewal and repair of top boards caused the author to try the substitution of hardwood boards with rounded top edge in place of the softwood top board with its iron capping (see drawing No. 1,982). This was so successful that all new trucks built now are constructed in this manner, and when old trucks require to have the top board replaced, tuart or wandoo planks with the rounded top edge are being fitted. These hardwood top boards have been in use for over two years and have given no trouble whatever, the new system proving in every respect successful, not only in doing away with the cost of renewals, but also avoiding damage to tarpaulins and other materials coming into contact with the loose ends of capping or loose screw heads. Taking each truck singly this may be considered a small detail, but when it is multiplied by the number of open trucks in use, it becomes a highly important matter, and to the practical engineer is another illustration of the truth of the saying, "Despise not the day of little things."

Diagrams, drawings, and photos referred to in this paper can be seen at the rooms of the Institution, St. George's Terrace, Perth.

WATER ANALYSIS.

SOURCE :—No. 1, Bunbury Bore ; No. 2, Loftus Street Bore, Leederville ; No. 3, Lime treated Victoria Reservoir Water.

CONSTITUENTS.	GRAINS PER GALLON.		
	No. 1.	No. 2.	No. 3.
DATE TAKEN.	27/10/'08.	May, 1909.	29/10/'09.
TEST NO.	1314	1494	2745
Alkaline Chlorides ...	10.33	27.33	10.5
,, Sulphates ...	Trace	2 98	...
,, Carbonate ...	2.19	13.3	...
,, Hydrate ...	...	...	...
Magnesium Chloride ...	...	...	1.49
,, Sulphate ...	...	...	...
,, Carbonate ...	2.31	1.21	1.04
Calcium Chloride ...	...	...	...
,, Sulphate ...	...	...	1.53
,, Carbonate ...	3.12	2.12	2.09
Iron Oxide and Alumina ...	Trace	.14	Trace
Silica	.28	3.15	1.05
Organic Matter	Trace	...	2.3
Total Solids ...	18.23	50.23	20.0
Total Hardness ...	5.9°	3.57°	5.5°
Temporary Hardness ...	5.9°	3.57°	2.77°

MUNICIPAL ENGINEERING.

(By Henry T. Haynes).

Municipal engineering covers so wide a range of subjects that one feels a difficulty in knowing just where to begin; and, moreover, it is all so utterly commonplace and simple, at least to the man in the street, that one becomes conscious of the futility of attempting to impart any knowledge concerning it. As, however, this paper has been prepared for engineers and not for the man in the street, the author trusts that it will not only be interesting but in some measure instructive. The constructive work of a municipal engineer may fairly be said to include not only the apparently simple and prosaic work of road and street construction and cleansing, but drainage, lighting, street tramways, refuse disposal, baths, parks, water supply, and a host of other no less important undertakings.

The administrative work calls forth much organising skill, tact and diplomacy; the irate ratepayer and disappointed councillor must alike be appeased. The unsatisfactory workman must be dispensed with, but without causing rupture with the whole of the employees. Firmness must be a prominent characteristic, and whatever may be the conduct of those with whom his position brings him into regular contact, the engineer must conduct himself as a gentleman. In addition to a thorough technical training, the municipal engineer must have some knowledge of commercial methods. He must be able to analyse costs and know the value and use of such analysis; without this there can be no economic administration. A piece of work may be done cheaply, but the reason should be known, and it is just as important in this case as when the work costs more than it should. The different classes of material, their respective quantities per unit of area, the value of each of these and of the labor engaged thereon should be carefully tabulated under various headings descriptive of the general nature of the work performed. This, of course, takes time and time means money, which the municipal authority is ill disposed to devote, being as a general rule unable to understand the value of such analysis and quite unaware to how great an extent such analysis, if carefully and systematically kept, would contribute to economic production when in the hands of capable and experienced men. Another value of such analysis is that it enables the engineer to discover at once the cause for any marked increase in cost and, further, it shows him in what particulars, if any, costs may be reduced. In road-making, its value is seen in so far as it shows whether the workmen are handling the average quantity of material, and whether the correct quantity is being applied. To know merely the cost of the whole or even the cost per chain is unsatisfactory because there are so many causes which contribute to the total cost that the cause of any variation from the average can only be ascertained by a minute analysis.

If a municipal authority were asked to define the function of the engineer one would expect to hear the American rather than the English definition,

for without doubt the municipal engineer who can get twice as much out of one dollar as any ordinary man can out of two is much more highly esteemed than he who has merely the" art of directing the great sources of power in nature for the use and convenience of man." For of all the requirements by those in authority over the municipal engineer a maximum of work for a minimum of expenditure is the chief, and indeed so strong is the demand for this that quality and permanence is ofttimes sacrificed for quantity and expediency. Hence he who has discarded " the much-vaunted empirical rule of thumb and has elevated to the heights of science the observations of exact practice and the exercise of pure reason " frequently fails to give satisfaction to his employers.

One of the chief difficulties with which the municipal engineer in this country has to contend, and which is a source of much disappointment and not infrequently failure, is, as a German professor once said in another connection, that the employer has, as a rule, a violent suspicion of the expert and a strong belief in the untrained, unpaid amateur, allowing the expert to advise and the amateur to decide. " The German," he said, " had no such fear. He saw dangers in red tapeism at the hands of highly trained officials, but he found them much less than the dangers arising from the decisions of well-meaning but untrained and inexperienced amateurs," and it will not be until the well-trained and experienced municipal engineer is allowed reasonable freedom to exercise his skill that the public will realize to the full, the benefits he is able to confer, for, as Sir William Henry Preece well says, " The engineer is not only a benefactor to his race, but he is a necessity of the age."

Before leaving this part of the subject, it might not be out of place to draw attention to the growing practice of local authorities to "create municipal engineers" and by the mere passing of a resolution that he, who has never had any technical training but who happens to hold the office of clerk shall be the " municipal engineer." The author ventures to suggest that the Institution might well make some representations on this subject to the proper authorities, not only in the interests of the profession, but of the general public.

Road Making.

The subject of road making is so familiar that it is difficult to communicate anything new regarding it. Still, as one observes the grading of roads in some districts, there is reason for believing that there is yet some ignorance abroad, at least as to the principles which govern the effect of traffic and wear and tear of roads. The author has observed—as no doubt also have many of the members—that the footpaths on the high side of certain streets which have a natural transverse slope is higher than the private land adjoining, due probably to the fact that no levels were taken when the centre of the road was first constructed. The question of gradient, particularly of town streets, is governed largely by the existence of buildings

on either side and hence as development extends and necessity for drainage, etc., increases, the municipal engineer finds much difficulty in dealing with the matter, whereas if when towns are laid out, as is being done throughout this State every year, levels were taken and plotted and gradients marked thereon much expense might be saved later on. Gradient is important, 1st., from the view of expenditure of tractive energy; 2nd, from the view of wear and tear—maintenance—both of which, from the engineering point of view, mean money. The energy expended in drawing a load in a wheeled vehicle has never, so far as the author knows, been accurately determined: almost every investigator obtains different results, due possibly to a variation in the conditions which govern the determination. The elements which enter into the consideration are wheel diameter, axle friction, road resistance, which is made up of gradient and general condition. With the wheel diameter and axle friction the municipal engineer has not much to do, but with the road resistance he is much concerned. Sir John Macneil, who conducted experiments on the road between London and Shrewsbury, concluded that the tractive force required to draw a load of 1 ton along a well-made and level pavement was 33 lbs. and in ascending an incline it is approximately equal to the gross load divided by the rate of gradient, plus that necessary to move the load on the level. Hence it is manifest that for economic reasons a road gradient is a matter of much importance and should not exceed 1 in 40, though for short distances a much stiffer grade is sometimes permissible, and in town experience the municipal engineer is compelled by circumstances to adopt it. Too quick a grade is detrimental also from a maintenance point of view, and the scouring effect of storm water. The cross fall of a road should never be more than 1 in 24. If, therefore, the longitudinal gradient exceeds this to any great extent the storm water instead of flowing to the side channels takes a more or less straight course down the road, washing out the binding material and destroying the road. The flattest permissible gradient consistant with good drainage in town experience is 1 in 200, and with this it is found that gully holes should not be further apart than 200 ft., otherwise storm water accumulates inconveniently with every sharp shower. The amount of crown or form of transverse section provides an inexhaustible topic for debate between the municipal engineer and those in authority: it is nearly always too great or not enough. The author's practice has been to allow half an inch per foot for macadam and gravel roads on ordinary grades and ⅜ of an inch for wood-paved and asphalted roads, though for the latter a flatter cross section would be better.

The City Engineer of Omaha, U.S.A., has given for asphalt roads the following formula:—

$$C = \frac{W(100 - 4P)}{5000}$$

in which C=the crown in feet, W=distance between kerbs in feet, P=per cent. of longitudinal grade. The author is of opinion that this gives

too much crown for an asphalt road, which really requires less than any other form.

With the general principles of road construction as laid down by Macadam, Telford and others, you are all doubtless perfectly familiar; and the thought which occurs with the memory of the names of these famous men is that we hear little of Telford in these days, although most of the roads now made are more after his method than that laid down by Macadam. Macadam's method, as you may remember, was simply to spread upon an approved formation a layer about 10 inches thick of 2-inch broken stones, while Telford's method was to lay a bottom course of stones from 6 to 9 inches in depth, carefully set by hand, on their broadest edge lengthwise across the road all cross bonded, so as to form a close firm pavement, and thereon to spread a 7-inch layer of 2½ inch broken stone. The method most usually adopted in this country is to first spread a layer of stone broken to 4 inches, about 8 inches thick and thereon another layer about 4 inches thick broken to 2 inches; so that really our roads should be termed Telford roads rather than Macadam roads. However, the principles of these road-makers holds good to-day, while the details of their application varies with local conditions in almost every country in the world. Road-making in Perth is quite a different business from road-making in Melbourne, for example. The author has made many roads on the clay subsoil near Melbourne after Telford which have withstood heavy traffic remarkably well, but if so made on the sand here would probably have gone to pieces. Likewise let any one accustomed to our methods be careful how he applies them on a wet clay subsoil. Road-making in this city as in many others, has been somewhat of an evolution. Many here will probably remember the old sand tracks, then the 9 ft. wide strip of macadam bordered by timber planking fastened to stout stakes driven deep into the sand. This method was not held in universal respect, though the principle of it was good, being to prevent the road spreading into the sand at the sides, which in the case of so narrow a track and under a concentrated traffic it was almost sure to do. Following this came the addition of a narrow strip of a few feet in width on each side, bordered by blocks of ironstone or sandstone, roughly squared; and, as time went on, the removal of the timber border. With the wider road, settlement was less apparent and probably less real, however the stone margin has been universally adopted, and if well squared stones of about one cubic foot bulk are used and well bedded the results are satisfactory.

In early practice limestone was much used for the foundation layer, brought in lumps and broken on the formation. This method was found to produce a more solid base than if the material was broken elsewhere and spread loosely upon the excavated formation. The usual thickness of this material was about 8 inches. This layer was covered by a wearing surface of diorite, granite or ironstone metal. Examination of some of the old roads has revealed the fact that although the limestone had not

come into direct contact with the traffic, yet in many places it had become quite pulverised, due apparently to having been crushed or pounded by the traffic. In later years the best quarried ironstone has been used for the base course. It is found to be much stronger, gives a much longer wear and binds by the natural process of oxidation into a compact mass; indeed, for the light traffic of suburban area there is probably no material which, relatively to cost, wlil give better results than a 4-inch layer of clean quarried ironstone broken to 2½-inch guage on a 6-inch base course of the same material broken to 4-inch gauge, all voids being well filled in with finer gauge of the same material and finished with the usual rolling to consolidation. Such a road, if given a proper cross section, will wear smooth, create very little dust, is always clean, and will last six or seven years without repair. This, of course, is for roads carrying the ordinary light traffic of residential suburban area. The question of using diorite and granite metal mixed is one regarding which there has been much controversy in certain quarters. The author is of opinion that one of the principles to be observed in road making is uniformity of hardness and toughness of material, and that inasmuch as there is a variation in this respect in the diorite and granite available here it is a mistake to mix them.

The material used as a binder of the stone is a matter of considerable importance and usually difficult to obtain at a reasonable cost. The practice laid down by Macadam was to use nothing other than the stone itself and to have sufficient labor constantly on the road to keep the metal raked in position until consolidated by the traffic. In these days such methods would hardly be tolerated and even if they were with the stone at our disposal the results would be very unsatisfactory because long before natural settlement took place even with the added advantage of the steam roller, large quantities of dust and horse droppings would become incorporated with the metal. The present age demands that the newly spread metal shall be consolidated and bound within a few days after being applied on the road. To achieve this various binders are used, amongst which may be mentioned limestone siftings, ironstone gravel, diorite siftings, and tar; none of these materials are without merit. The great consideration is to select a material which will produce a minimum of dust in the process of wear and which at the same time will render the surface so compact as to make it practically waterproof and easy to keep clean. The materials which in the author's opinion will best fulfill these conditions are 1st. tar, 2nd. stone siftings, with a small percentage of gravel, say 25 per cent. Gravel alone and limestone siftings alone do not fulfil the conditions, but by reason of their comparative low cost the municipal engineer is required to use them whether he pleases or not. The author when in the service of one of the municipal corporations in this country frequently pointed out the unsuitability of gravel from the point of view in question. In 1904 he reported that " From a scavenging and dust point of view ordinary macadam and gravel roads and paths are undesirable

in a busy city ; it is impossible to keep such roads clean and in good order without great cost, and if watered sufficiently to keep the dust down, particularly during the very hot season, the cost would be excessive."

The use of tar was first availed of as a binder and dust reducer by the author some years before his arrival in this State, and the results were so very satisfactory that he lost no time in advocating its use here. The first piece of road he was allowed to operate upon was on the side of St. George's-terrace, opposite to the Post Office : this in order that the "authority" might be quite sure it would fulfil what was claimed for it. Probably it did, because next year some 4,500 sq. yards were laid in Adelaide-terrace from the Causeway westward, followed by St. George's-terrace between William and Barrack streets, one half width being done during the year 1905 and the other during 1906. And in order to show members the character of the work, I have a piece recently taken up by the sewage contractor from the road adjoining the Commercial Bank. This had been down for nearly five years, and the tar, it will be observed, is still bright, while the material itself is very dense. Work of this character seems to fulfill all the requirements of an ideal road.

The use of tar in road construction has two methods of application depending upon the object to be attained. By tar macadam is understood suitable metal coated with tar and then spread upon the roadway. Tar dressing is an application of tar to an ordinary macadam or other form of construction. The success of either depends upon quite a combination of suitable conditions. Thus in tar macadam the stone used must be thoroughly dry and warm. In top dressing the surface coated, whether it be ordinary macadam, tar macadam, wood pavements, etc., must be perfectly dry. So important is this that in parts of England and elsewhere, where it is difficult to obtain a quite dry surface of road, hot rollers, blasts and such-like contrivances are used to produce the required condition.

Another very important condition necessary to success is that the surface operated upon shall be perfectly even, without any depressions. Tar work is the wearing surface and uniformity of thickness is important, otherwise unequal settlement results ; and although the settlement is so slight as not to be noticeable during dry weather, the slightest shower of rain shows up the defect.

In giving a tar macadam wearing surface to an old road, the form of construction which in the author's opinion gives the best results is first to bring the existing surface to a proper contour by the usual methods of scarifying and spreading clean metal, have the surface consolidated and finished with as much care as would be bestowed upon it if that were to be the wearing surface, but leaving about 2 inches for the tarred metal ; allow sufficient time for all moisture to disappear, then sweep off all surplus binding and dust so as to produce a perfectly clean surface. The applica-

tion of a machine sweeper will brush out the joints of the stone so as to give a good key. The tarred metal is then spread to a uniform thickness of 3 inches, which will roll down to 2 inches; after rolling to a perfectly even surface keep the traffic off for twenty-four hours and then throw it open, but let it be visited during the next day or so to rectify any damage that may be done by the traffic. If, however, the material has been properly prepared and applied under suitable weather conditions it will not sustain any damage under ordinary traffic. After the space of two or three weeks give it a coat of tar and fine stone siftings about the size of wheat grains, and have a man to keep the siftings well swept in for a day or so. This will produce an ideal road—smooth, noiseless, dustless, and waterproof, easily kept clean and from a sanitary point of view perfect. If it be desired to construct a new road with a tar macadam surface, the better plan is to start in the ordinary way of plain macadam roads and after the road has been open to traffic for, say, three months make good any depressions which may have appeared and apply the coat of tarred metal as already described. The author does not consider there is any advantage to be gained in this country of adopting the English practice of constructing tar macadam roads in three layers of tarred stone, first because we are not subject to so much wet, our drainage is perfect and our climatic influences are different. As before indicated, an excess of tar is to be avoided because during the hot esason, with the sun at 150 degrees the tar will soften and act as a lubricant and the mass will work up into rolls instead of remaining where it was placed.

As a dust preventer, a coating of tar and stone siftings upon the surface of an ordinary macadamized or gravel road gives excellent results. This was introduced by the author into Perth some years ago and has given much satisfaction, though, of course, it cannot rectify the defects of an uneven surface. The preparation of the mateiral is of the utmost importance. The stone should be tough, hard and of a rough fracture; it should not be of uniform gauge but have a sufficiency of smaller stuff to ensure a complete absence of voids in the finished work. Stone passed by a 1¼ inch screen and held on ⅜ inch screen is the most suitable for a wearing surface. The stone should be measured in a box as for concrete, unless the mixers are experienced and reliable men and able to judge as to the quantity they are handling. The tar also should be measured and by means of heavy rakes, forks and shovels the mass should be turned until the tar coats every particle of stone. The work is best done during the summer time when the stone is warm and the tar should be hot so as to make it more easy to work. The tar is prepared from coal tar and used sometimes with a proportion of pitch added. The ideal to be aimed at is to obtain a material which will not be too plastic in summer nor too brittle in winter, hence the material that would serve in one country will not serve in another. Inasmuch as tar even from the same gas works differs in quality from time to time, much care and watchfulness must necessarily

be bestowed upon its preparation for road work. Chemical analysis, so far as the author is aware, has not been able to distinguish which tar is good or bad from a road-maker's point of view.

Attempts have been made to describe the tar to be used. In America what is known as No. 4 distillate is much used. " It has a specific gravity of 1.30 and contains about 65 to 70 per cent. of bitum n soluble in carbon bisulphate." The author's specification prescribes that the tar is to be gentle heated in a suitable boiler and boiled until all water, naphthaline and amonicicol liquor and lighter oils are evaporated and the tar reduced to a consistency such that when cold it remains tough and ductile and can be drawn out in long thread-like filaments.

As to the quantity of distilled tar that is required per cubic yard of stone, this varies with the quality and gauge of the stone ; thus the Melbourne 1½ inch basalt requires 13 galls., while fine screenings requires about 25 galls. per cubic yard. Darling Range diorite requires for 1½ inch stone 10 galls. and fine screenings about 18 galls ; but there is no definite rule. The better way is to stand over the work and use one's judgment It is better not to put enough than too much. The former error can be rectified just before using the material.

From some old records I have supplied tables of costs of work actually done, which may be instructive.

Details of Cost —Municipality Hawthorn, Victoria

Auburn-road, S. Old metal road, top coated with clean 2-inchbasalt) and binded with tarred ¾ inch basalt. (Date, October, 1899. Area covered, 1,822 sq. yards.

	£	s.	d.
2 in. metal, 127 cu. yds.	£38	2	0
¾ in. metal, 70 cu. yds.	22	10	0
1,200 galls. tar	16	5	0
Labor mixing and spreading tar	5	12	6
Labor on road	11	16	0
	£94	5	6

Cost per super yard, 1.034s.

Auburn-road, 2nd section. Treated as above. Area, 1,854 sq. yds

	£	s.	d.
2 in. metal (clean), 175 cu. yds.	£52	10	0
Tarred ¾ in. metal, 66 cu. yds.	42	18	0
Dry siftings, 4½ cu. yds.	1	7	0
Tar, 270 galls.	3	13	1½
Cartage, 16½ days, at 7s. 6d.	6	3	9
Labor on road	12	10	3
	119	2	1½
Less 12½ days labor scarifying	4	7	3
	£114	14	10½

Cost per sq. yd., 1s. 2¾d.

This piece of road is in a business locality and lies between the main road and railway station, and therefore has a fairly heavy commercial traffic, although no very heavy individual loads and nothing in the way of maintenance was done to it for exactly one year. On its birthday it received the following top-dressing :—

300 galls. tar at 3¼d.	£4	1	3
5 cu. yds. siftings, at 6s. 6d.	1	12	6
1 horse and dray		10	0
2 days' labor		14	0
Boiling tar		3	6
	£7	1	3

Something under 1d. per sq. yd.

Then on the same day the third year £7 15s. 5d. was spent top-dressing the same area, so that the annual maintenance worked out at 1d. per sq. yd.

Records show that for top coating adjacent portions of the same road with clean 2-inch metal and binding with stone dust cost 8½d. per sq. yd and when the binding was with loam the cost was 6½d. per sq. yd.

The fair average cost for top coating old macadam roads in Hawthorn with tarred metal, the same as has been done since in Perth, was 1s. 3d. per superficial yard and 1d. to 1¼d. per super yard per annum afterwards. This, with labor at the low rate of 10½d. to 11¼d. per hour, cartage 1s. 3d. per hour, tarred stone 12s. per cu. yd., clean stone 6s. 6d. per cu. yd., tar 4¼d. per gall.

Comparing with similar work done by the author in Perth at the following rates : labor 1s. to 1s. 3d. per hour, cartage 2s. per hour, tarred stone 20s. per cu. yd., clean stone 12s. 7d. per cu. yd., tar 9d. per gall. St. George's-terrace, from which the sample produced was obtained, cost 2.36s. per super yd. and 3,253 sq. yds.

17 hours scarifying, at 7s. 6d..........	£66	7	6
5 cu. yds. gravel ballast, at 6s. 3d.....	1	11	3
290 cu. yds. tarred metal, at 20s.......	290	0	0
9 cu. yds. tarred siftings at 25s........	11	5	0
33 cu. yds. stone dust, at 7s. 4d.......	12	2	0
50½ hours steam rolling at 5s..........	12	12	6
Cartage of metal	20	7	6
Labor..............................	28	0	0
Mix	1	6	1
	£383	11	10

April, 1906.

The total area of this class of work carried out by the author amounts to 30,000 super yds., at an average cost of 2s. 3d. per yd. The average cost of top dressing with clean metal and binding with gravel is approximately 1s. 6d. per super yd, but in comparing the relative cost consideration must be given to relative merit. In a tar macadam road there is no dust, no mud, small cost for cleansing and upkeep and much higher efficiency, and what the author sta ed in his annual report to the Perth Corporation in November, 1908, may be repeated here:—"The tar macadam road is the one which best resists the destructive action of motor traffic, besides being an ideal road for ordinary traffic, is almost noiseless and not of itself a producer of mud or dust. There can be no doubt but that as the tar coated areas increases the unpleasantness arising from rough, noisy and dusty streets will diminish." Some particulars with regard to the quantities of material required in top coating tar composition pavements may be of interest. They are the results of the author's actual experience, and refer to coating with tar and stone siftings.

Quantities.

Area in sq. yd.	Sq. yds treated per min. per man.		Stone in cub. yds. per sq. yd.	Galls of tar per sq. yd.	Cost per sq. yd.
1,000	2.04	not rolled	.0075	.270	1.98d.
980	2.08		0074	275	1.90d.
948	1.01	rolled	.0066	.242	1.66d.
1,000	1.56		.0105	.270	2.74d.
826	1.74		.0073	.278	1.937d.

Wood Paving.

A paper of this kind would scarcely be complete without some reference to wood paving and when one considers the large extent to which it has come into use it seems almost incredible that in November, 1884, a scientific board appointed by the N.S.W. Government to enquire into the matter of wood pavement, strongly urged that the paving of Sydney streets with wood should be discontinued on account of its possible injury to health. The objection was not only "to the material itself, but to every known method of construction," and it is probably due more to the forcible reply of A. C. Mountain, M.I.C.E., the then City Surveyor, than to any other influence that the recommendations of the Board were not adopted. The first piece of pavement laid in Australia was during the year 1880, when several experimental areas were paved in King-street, Sydney, the timbers used being red gum, blackbutt, blue gum, white box, ash, cedar, brown pine, and baltic deal. After fourteen months' trial an examination was made and the red gum, blue gum and blackbutt showed practically no signs of wear; the box and ash were reduced ⅛ in.; the cedar, brown pine about ¼ in., and the baltic deal ⅜ in.* West Australian experience has been limited to jarrah, which perhaps is to somewhat be regretted, not because jarrah is not a very excellent timber, but because from our

vast timber resources there may be even better. The timber we have used has all been untreated, some after being in store five years, other used fresh from the mill. Whether green or dry, there appears no appreciable differenec in the wear. After being subject to traffic of a fairly heavy kind, ten years' wear does not show more than ¼ inch. Great trouble has, however, arisen on account of the blocks not being creosoted or powellised. The expansion and contraction appear to be equally troublesome with the green timber as with the dry. In order to ascertain what the maximum expansion would be, in 1905 the author made some experiments with a view to discover if possible the maximum expansion of wood blocks due to moisture. The blocks were dressed to measure 6 x 9 x 3 in. They were placed side by side on a gauge and the length measured, then placed long way on and measured; after this they were weighed and then immersed in water in a shed for 257 hours and re-weighed and re-measured. The result is set out in the following table:—

Dry Jarrah.

No.	Weight in Lbs. Dry.	Wet.	Difference.
1	3.885	4. 416	.531
2	4.219	4.605	.386
3	4.000	4.375	.370
4	4.240	4.769	.529
5	4.500	5.066	.566
6	4.265	4.658	.393
	25.109	27.889	2.780

Expansion 9 in., way 3 1-16 in.
Expansion 3 in., way ⅝ in.

Green Jarrah.

No.	Weight in Lbs. Dry.	Wet.	Difference.
1	5.359	5.922	.563
2	6.544	6.817	.273
3	6.357	6.623	.266
4	6.534	6.769	.235
5	6.050	6.406	.350
6	6.389	6.695	.306
	37.233	39.232	1.999

Expansion 9 in., way ⅛ in.

Expansion 3 in., way ¼ in.

* Proceedings Inst. C.E. vol. xciii. A. C. Mountain, M. Inst. C.E.

Green Tuart.

No.	Weight in Lbs. Dry.	Wet.	Difference.
1	6.696	7.000	.304
2	7.174	7.344	.170
3	7.096	7.298	.202
4	7.288	7.441	.153
5	7.346	7.528	.182
6	7.335	7.545	.201
	42.935	44.156	1.221

Expansion 9 in., way ⅛ in.
Expansion 3 in., way ⅛ in.

At one time it was thought this variation in size could be provided for by the insertion of a mastic joint, and while this did very well for a year or so, the excessive expansion soon squeezed it out, then during the contraction period of the summer the open joints became filled with dust or the material used in top coating the blocks with the result that when expansion again took place a further quantity of the mastic rose to the surface and had to be removed until all had disappeared, then came the necessity to remove an entire row of blocks. The expansion of untreated jarrah blocks is not less than ¼ in. per foot, while in the treated blocks there is practically no expansion at all, particularly if they are kept coated with tar and sand during the wet season.

n laying wood pavement the usual practice is to provide a foundation of cement concrete 6 in. thick, floated over to the correct cross section, and then to pack the blocks as closely as may be with their greatest width across the line of road. The method originally adopted was to keep the blocks apart with a view to minimise slipping of horses, but that idea has been abandoned. The depth of the blocks was originally fixed at 6 inches, but experience has shown this to be unnecessary. Many of the London vestries use them 4½ and 5 inches deep and in some instances in Melbourne old blocks have been recut to 4 inches. The permissible maximum grade for wood paving is 1 : 25 in countries liable to much frost, but with us much steeper grades may be adopted without danger. Sydney has some at 1 : 12 and in our own town the grade of the Barrack-street bridge is 1 : 13 and accidents due to it are unknown.

Amongst the general services which it falls to the municipal engineer to administer may be mentioned street cleansing, disposal of garbag'e allaying the dust. These, though apparently simple, require a good deal of experience and organization to bring about satisfactory results, particularly in populous centres. The system which in the author's experience gives best results is to divide the area into suitable districts of a size such that one man can cover in a day. Perth Municipality has about 80 miles

of streets and in 1904 was blocked off into seven divisions, and the quantity of detritus collected from the street sides averaged 819 loads of about 1¼ cubic yards per month. The total for several years a set out in the following :—1903-4, 10,015 loads ; 1904-5, 11,498 loads ; 1905-6, 12,438 loads ; 1906-7, 12.324 loads ; 1907-8, 6,595 loads.

The drop in the last-mentioned year was due to a reduction in the labor employed, not to the reduced necessity of cleansing. From a purely engineering view this may appear a matter of small interest, but from the hygienic point of view, which should never be lost sight of by the municipal engineer, it is very important—cleanliness is an all important matter and better leave an area in a state of nature if such were possible than by developing it polute it and be content to leave it so. Many eminent authorities have declared over and over again that a great deal of sickness is directly traceable to dirt and authoritative opinion has expressed that much of the excessive diarrhœa of towns is due to air-borne poison in the form of dust. Indeed, one's own personal discomfiture arising from having to breathe in dust-laden atmosphere should be sufficient reason for putting forth every effort to combat it. The average cost of cleaning the 45,277 square yards of wood paving in Perth was 10.6d. per 100 square yards during 1904-5. and the amount of detritus consisting almost and entirely of horse manure is fairly constant at from 500 to 540 loads per annum.

Street Watering.

The system found to give best results is to allot an area to each water wagon. The wagons are nominally 400-gall. capacity, constructed of wooden or iron tanks. One load will cover approximately 2,200 square yards of road surface. The time occupied in filling and discharging a load varies somewhat and depends upon the water pressure and size and number of holes in the cart spreader. Systematic checks have been kept and the results show that during daylight the average time actually devoted during the year 1904, to filling was 5.24 minutes per load, and the time between being full and commencing to empty 1.27 minutes, the time occupied in emptying 5.42 minutes, and the time between being empty and commencing to refill 1.92 minutes. The time will vary each year to a slight extent, but 15 minutes per load is a fair average allowance.

In Perth the dry season extends over a period of about 240 days per annum, hence street watering is a matter of considerable importance from a road maintenance point of view. There is practically no rainfall between the months of October and March, and the evaporation is comparatively high. With the perfect drainage of the road bed which our sand formation provides and the steady heat of the sun day after day, the material of which the macadamized roads are constructed must necessarily become very dry unless frequently watered, and when dry very soon disintegrates with the influence of traffic. Roads on a clay formation are not subject

to this disability and rarely require water for maintenance purposes. The following table gives the quantity of water used :—

1903-4	21,359,000 galls.	cost	£2,685
1904-5	20,503,000 galls.	,,	£2,724
1905-6	30,354,650 galls.	,,	£3,368
1906-7	37,220,550 galls.	,,	£4,172
1907-8	23,363,100 galls.	,,	£2,189

Costs Analysis of Road and Path Construction.

Top dressing metal roads with 1½ in. metal and gravel binding. Costs per square yard.

A	8,450 sq. yds.	1.86s.
B	2,467 ,, ...	1.64s.
C	5,199 ,, ...	1.33s.
D	2,990 ,, ...	1.45s.
E	4,488 ,, ...	1.07s.
F	2,235 ,, ...	1.34s.

New construction. Blue metal on ironstone ballast.

A ...	568 sq. yds.	10 in. thickness	3.15s.
B	1,357 ,, ...	10 in. ,, ...	3.06s.
C	1,532 ,, ...	10 in. ,, ...	3.15s.

Gravelling paths.—35,000 sq. yds., cost varies from 9d. to 1s. per sq. yd. for 3 in. coat of ironstone gravel.

Top dressing of roads with tar macadam.

A	3,280 sq. yds.	2.39s.
B	3,400 ,, ...	2.14s.
C	1,056 ,, ...	2.94s.
D	3,093 ,, ...	2.61s.

Tar and dusting wood paving.

A	4,520 sq. yds.	2.91d.
B	11,460 ,, ...	2.0d.
C	5,780 ,, ...	2.65d.

Stone Quarrying and Metal Costs in Pence per cubic yard.

	1/2/07 to 13/2/07	13/2/07 to 20/2/07	20/2/07 to 27/2/07	14/3/07 to 27/3/07	27/3/07 to 10/4/07	10/4/07 to 24/4/07
Spalling	13.8	13.0	13.58	14.09	17.1	13.05
Quarrying	8.2	7.6	7.76	5.29	5.7	4.20
Filling spalls	4.6	5.7	5.36	6.04	7.1	5.37
Feeding Crusher	3.6	3.0	3.06	2.74	2.8	2.05
Repairs	4.2	1.11	1.02	.80	1.0	.07
Train	.17	.20	.01	.08	.3	.18
Sharp tools	1.70	2.6	2.34	2.14	2.53	2.64
Steam drill	1.62	1.45	1.94	2.34	3.42	2.27
Load trucks	0.32	1.60	1.48	1.83	2.0	2.45
Engine driver	3.20	1.80	1.89	1.89	2.3	1.80
Carrying wood	.34	.41	.43	.36	.38	.41
Loading holes	1.28	1.11	1.05	.90	1.30	1.09
Cleaning up	.23	.44	.49	.56	.60	.90
Oiling up	.28	.10	.12	.38	.03	.19
Mix	.40	.52	1.10	.55	.62	.74
Filling spoil	—	—	—	5.77	6.69	4.01
Filling cubes	—	—	—	.05	.06	—
Holiday	—	—	—	—	4.41	—
Drain	—	—	—	1.29	1.38	.15
Wheeling metal	—	—	—	.18		
Total costs	3/9	3/4.6	3/6	3/10¾	5/-	3/7

Railway freight, interest, and sinking fund on plant, local cartage brings the price up to 12/6 per cub. yard on the road,

Average wages per hour :—Foreman, 1/3; laborers, 1/1½ and 1/- ; horses, drays and drivers, 2/-; steam rolling, 5/-; gravel, 6/4 per cub. yard; ironstone, 6/4 per cub. yard; coal tar, 9d. per gallon.

REFRIGERATION MACHINERY, WITH A DESCRIPTION OF THE LINDE SYSTEM.

(By J. W. Henderson.)

Refrigeration of to-day is the direct outcome of scientific research, and originated in the dim past, as the direct result of the common need and shares that distinction with electricity. The objects of all freezing mixtures, refrigerating machines and apparatus is to reduce the sensible temperature or abstract latent heat from some substance whether olids, liquids or gases, and its application to these objects has become so general, that an extended list of purposes to which it is applied is not possible in paper.

The use of freezing mixtures for artificial cooling has been known for many centuries. Taking advantage of the law that when two solid bodies unite chemically to form a liquid a low temperature is produced, freezing mixtures consist of certain salts and water acids or ice, and the tendency to form liquid is so strong, the heat is abstracted from surrounding substances at a greater rate than it can be supplied, with the result that the temperature falls until a point is reached where there is a balance. The temperature of freezing mixtures and the temperature of substances being cooled become equal and by conduction, radiation or convection, the temperature of both substance and agent will rise again unless some means are adopted to renew the agent, or provision made for the rejection or dispersion of the heat extracted.

The use of chemical freezing mixtures is not general, and cannot be worked on a large scale commercially, on account of cost in working and maintenance. However, they are extremely convenient in laboratory work, and their further notice is not necessary for this paper.

The use of ice however, is extensive, and it is applied to the cooling of substances. The melting point of ice is 32° F. and this temperature remains constant in the ice, so long as any ice remains. The higher the temperature of surrounding substances merely hastening the melting process.

The latent heat of ice being 142.6 B.T.U. per lb of ice, there is a considerable potentiality for abstracting heat for cooling rooms, preserving perishable articles, cooling liquids, etc., but the melting of ice alone can never produce a temperature below 32° F., and a freezing temperature cannot be obtained by the melting of ice itself, and it tends to produce a dampness on the articles which render them more liable to the multiplication of bacteria, even after the reduced temperature. Better results would be obtained by using ⅓ salt and ⅔ ice, and keeping the ice in a V shaped iron trough, under which a gutter is placed, the low temperature of the receptacle would cause the moisture to freeze on to it and when melting could be drained to the outside of the box or room with a trapped drain. This is practically the only freezing mixture used, and if ice cannot be obtained from nature, mechanical apparatus is used to make it.

The use of ice is now giving way to more perfect systems or mechanical refrigeration. The power of refrigerating machinery is rated in terms of given weights of ice melted per 24 hours.

In 1729, Fahrenheit thought he had reached the limit of reduction in sensible temperature with a mixture of snow and salt, started the notation of his thermometer from 32° below the freezing point of water. Since then lower temperatures have been obtained, and the theoretical point of absolute temperature now used -461° F. F. has been approached as near as -443° F. by Olozewski in his experiments in the liquifaction of helium, the new gaseous element discovered in the atmosphere. At -443° F., it still remained a gas but it is probable it would become a liquid at a temperature of about -570° below zero F., this temperature must therefore still be above absolute zero ; at any rate it seems a different absolute zero point will have to be accepted, and our conceptions in Thermodynamics will be altered.

In 1755 Dr. Cullen produced a machine using water evaporated under nearly perfect vacuum. Leslie in 1810 improved it by using sulphuric acid and water, Hague in 1834 invented a machine using volatile spirit of cantchone.

The first cold air machine of which we have any record, was made by Dr. John Gorrie of New Orleans, U.S.A., and to him belongs the credit of inventing the cold air machine.

Carre in 1850 invented the ammonia absorption process, Harrison, Twining and others using a compressor with ether in 1860. In 1861 Kirk's air machine appeared working in a closed cycle and adapted for making ice. This machine was a practical success.

Linde, who made the first study of the subject from a thermo dynamic point of view, in 1870, evolved both the carbonic anhydride and ammoma compression machines, and there are many others who have brought forward machines and agents up to the present day. However, there is little profit in going deeply into the history of refrigeration, further than it shows how it has progressed and how much better we are off to-day than some of the engineers now living were, during the early progress of refrigerating work, and to lead us to try and improve our existing methods, so that posterity will appreciate our work of to-day.

There are two distinct classes of machines and apparatus used for refrigeration, first, one using a permanent gas, second, those using a volatile fluid. As a convenience, class 1 may be taken first, not because they are the oldest, but because more progress has been made in the carriage and storage of produce, when it was thought that chemical agents were not suitable for use on ship board.

Compressed air machines consist of compressor, cooler and expansion cylinder, and is the reverse of a heat engine. The air is laden from the room by the compressor, compressed, passes through the cooler, is cooled down to about 10° above the temperature of the water circulating through the cooler, and expands in the expansion cylinder, to atmospheric

pressure, or thereabouts, and the air makes a complete circle through the rooms back to the machine.

In 1877 a compressed air machine was designed by Mr. J. J. Coleman, of Glasgow, and in 1879 one of these machines was fitted on board the Anchor liner "Circassia," which successfully carried a cargo of chilled beef from America to the United Kingdom, the first imported by aid of mechanical refrigeration, ice having been previously used.

The first successful cargo of frozen mutton was also carried from Australia by a Bell Coleman machine in 1879; other markers followed, such as Lightfoot, Hall and Haslem. The measure of refrigerating work performed by all these machines being the difference between the temperature of air drawn from the chamber, and the temperature of the air delivered to the chamber, multiplied by its weight and specific heat, which at constant pressure is .2379 = the number of B.T. lbs. of h at abstracted.

Could a machine be constructed with a reasonable mechanical efficiency to compress air to a temperature slightly above the temperature of cooling water, and expand it to a temperature slightly below the temperature required in the chambers, such a machine would approximate the ideal coefficient of performance as given by the equation $\frac{T}{T_1 - T_2}$ where T_1 = lower temperature absolute, T_2 = higher.

The efficiency of the process would be denoted by the equation $W = Q_2 - Q_1$ where W = work in equivalent B.T. Units.

Q_2 = the quantity of heat in B.T. Units given out a higher temperature.

Q_1 = the quantity of heat taken in at lower temperature.

$$E = \frac{Q_1}{Q_2 - Q_1}$$

Such a machine would require to use enormous quantities of air, with extremely large and mechanically inefficient cylinders and apparatus. Assuming that such a machine could be worked, delivering air at a temperature of −10° F., and rejecting it in the cooler at a temperature of 70°, the coefficient of perforamnce would be :—

$$\frac{461^\circ - 10^\circ}{70^\circ + 461^\circ - 10^\circ - 461^\circ} = \frac{451}{531 - 451} = 5.6$$

and it shows the heat extracted exceeds by many times the heat expended, and our machine at this range of temperature would abstract 5.6 times as much heat as the equivalent of energy to be supplied. This holds good for all working fluids and shows the importance of keeping the range of temperature as small as possible.

A heat engine, *i.e.*, an engine transforming heat into work, is the reverse of this, as shown by the equation :—

$$\text{Efficiency} = \frac{T_2}{T_1 - T_2}$$

A cold air machine in actual practice on air at atmospheric pressure,

and compressing to 60 ℔ absolute, and cooling in the cooler to 70° F., the rise in temperature in compressor according to the adialatic curve would be about 330° F., and on being cooled to 70°, in expansion cylinder, expanding along the adialatic curve to original pressure, the final temperature would be 110° theoretically, and the original volume would be less.

The ideal coefficient would be about 1. In practice this is not obtained, the final temperature is about 50°, and the actual effect about ⅝ of the ideal, this shows a heavy loss from the following causes :—

First. To keep the machine and apparatus in reasonable proportions, high pressure and consequent large range of temperature had to be adopted.

Second.—The moisture contained by the air often in sufficient quantities to saturate it, has an influence not to be neglected, as the vapour condensed, on the sides of the expansion cylinder, and parts with its latent heat of vapourization, so that the final temperature of the air is higher than it would have been had it been dry. The snow produced from this moisture accumulates around the orifice of discharge and cannot be readily utilised, and the work required to produce it is lost.

Third.—Waste spaces such as clearances, also decrease the efficiency. To overcome these losses several expedients have been adopted, such as water jackets on compressor, water injections into compressors. These reduced or assisted to reduce the adialatic curve of compression to the isothermal. Interchangers were fitted between cooler and expansion cylinder to deposit the moisture, and in some machines the air was in an enclosed cycle and did not come in contact with the substances to be cooled at all, but these are not now in use.

The coal consumption of these machines is from four to five times greater than machines of the present day using chemical agents. There is also trouble with the passages snowing up, and the low temperature 55° causes fog in the chambers, deposits moisture in the contents, and freezes it there, and leaves the surface damp when thawed. Another objection is the air is in contact with working surfaces in cylinders, and the oil imparts a mustiness to the rooms.

The expansion cylinder of a cold air machine is not only the cylinder that returns some of the work put into the air, but is also the vital part of the whole machine, for without it there would be no refrigerating effect, as the air expanding doing work, falls in temperature, while air expanding free does not, as can be seen when blowing air from a high pressure to the atmosphere.

If any engineer thinks his ammonia machine is a trial, he ought to consider the trials of the man in charge of a dry air machine. However, there are air machines working at the present day that are a credit to their builders, and though they are being replaced by chemical machines, it is because science has given us more efficient agents than air can be

with its present application, and not because the mechanical part of the work is inferior.

Class 2. Machines using volatile liquids may be divided into three types:—

(*a*) Machines using water where there is no recovery of the agent.

(*b*) Absorption machines, where the agent is recovered by means of absorption by a liquid.

(*c*) Compression machines, where the agent is kept working between a high and a low pressure, with no loss.

William Cullen, as far back as 1755, invented a machine on the vacuum principle, water being evaporated by reducing the pressure by an air pump. With the high vapour tension of water, a very perfect vacuum was necessary to obtain sufficiently intense refrigerating effect, and this led to the use of sulphuric acid as an absorber of water and vapour, which increased the ice-making capacity of the apparatus. In 1870, Wendhausen patented a vacuum machine capable of producing ice direct from water without sulphuric acid, but sulphuric acid could be applied if necessary.

In 1881, a machine was built and erected, designed to produce 12 to 15 tons of ice per day. It consisted of six circular ice-making vessels of cast iron, which would contain about 560 lbs. of ice. The vessels were closed at their bottom ends by air-tight hinged doors; water was allowed to flow through suitable nozzles at a regular rate. The upper part was connected with the air pump through a long horizontal iron vessel of circular section, containing sulphuric acid, kept in continual agitation by revolving arms. This vessel was water-jacketed to carry off the heat liberated during absorption of vapour.

The pumps had two cylinders, one large double-acting, and a smaller one single-acting. The large pump drew any air or vapour that passed the sulphuric acid, partially compressed it and delivered to a condenser, part of the vapour was condensed by cold water, the remainder with the air, passed along to the smaller pump compressed up to atmospheric pressure and discharged. The effect of the pump was such that a vacuum of .0097 lbs. per square inch could be maintained, .0484 lbs. per square inch was as low as necessary. The weak acid was concentrated in lead lined vessels, heated by lead steam pipes, the pressure being kept down by an air pump. The incoming weak acid was heated by the outgoing strong acid. Six blocks of ice, each about 560 lbs., were made in about sixty minutes after starting. The ice was opaque and porous, or what is called "rotten," caused by the water spraying into the vessels, freezing into minute globules which adhere together. Several attempts have been made to overcome the difficulty, more especially in America, where the vacuum and sulphuric acid have been revived. Vacuum ice is white because it is formed by small ice crystals, the faces of which have a refractive influence. This principle can be used wherever a surface condenser is available, or any pressure approaching a vacuum by connecting an air-tight insulated vessel containing water, to the apparatus with a tube,

and reducing the atmospheric pressure on the water when the water will be reduced in temperature by evaporation.

The evaporation of a water bag is another instance of reduction of heat by evaporation. The evaporation of water with its resulting absorption of heat is taken advantage of in mechanical refrigeration for condensing the vapour of chemical used. Vacuum machines are still used for small cooling effects.

Ammonia Absorption Machines.—Edmund Carre improved on the vacuum machines in 1850, and a few years later his brother Ferdinand Carre invented the ammonia absorption system. Various inventors and manufacturers have brought the system to greater efficiency, and it must be regarded as an important type, and consists of :—The generator or still, into which is poured .88 ammonia, 62 per cent. water, and 38 per cent. anhydrous ammonia. The temperature is raised to 270° by means of coils or pipes, with steam at 60 to 75 lbs. absolute, and the ammonia is driven off by heat. Analyzer.—The aqueous vapour passes into this and in doing so parts with some of its water at a temperature of about 380° F., and goes on to the rectifier, where it is still further cooled, and the remaining water vapour is condensed and drains back to the generator. The now almost anhydrous ammonia passes on to the condenser, where it is liquified. It is now ready to do its refrigerating work by expansion. As a liquid, it passes to an expansion or regulating valve, the pressure on condenser side of which may be 180 to 200 lbs. per square inch dependent of the temperature of condensing water, and the pressure on cooler coils or refrigerator to say 35 lbs., taking the heat necessary for evaporation from the surrounding medium, giving the refrigerating effect.

The ammonia gas or vapour, after leaving the cooler coils, has its pressure further reduced by means of a valve, and passes on to the absorber at a pressure of 20 to 30 lbs. The absorber, is arranged to allow the weak liquor from the generator to take up the ammonia gas coming from the cooler. The weak liquor trickles over pipes surrounded by ammonia gas, water at a temperature of 80 to 85° being circulated through the pipes to keep down the heat generated by the ammonia combining with the weak liquor. The strong liquor is then pumped back to the generator, passing through an economiser on its way, where it takes up some of the heat of the weak liquor, on its way to the absorber.

The steam supply for heating the generator may be the live steam from boiler, or exhaust steam from existing engines. If the latter, the pressure should be about 12 lbs. per square inch. Exhaust steam has been used for increasing the refrigerating capacity of steam driven ammonia compression plants and is well worth consideration, when more refrigeration is required, and there is little space to instal more boilers. The principal improvement in modern absorption plants consists of in using the regenerative principle. The condenser is in three parts, the analyser, rectifier and cold water condenser.

The analyser returns some of the heat to the economiser, to heat up the strong liquor from the absorber, and the condenser returns some of the heat to the absorber, as circulating water after passing over the condenser coils goes through the absorber pipes. Their efficiency is below compression machines owing to the heat or vapourisation extracted in the refrigerator being rejected in the absorber, and has to be replaced in the generator. The ammonia is not absolutely anhydrous, and the water contained reduces its effect as a refrigerant.

The cooling water has to take up nearly twice as much heat as compression systems. In practice it is found that a hot mixture of ammonia and water has a strong corrosive action on iron and steel, which increases the cost of upkeep.

The principle of which machines of this type depend to do their work is that when a gas changes its physical state to a liquid under pressure, and below its critical temperature, heat is given off without change of temperature, and becomes latent heat, and on being vapourised it re-absorbs that amount of heat at a lower temperature, and this heat is termed the "latent heat" of vapourisation.

From this it is apparent, other considerations being equal, the best liquid to use is the one that has the highest heat of vapourization, as it allows of the least quantity being applied for the refrigerating effect required.

The latent heat of different liquids varies considerably, and even for the same liquid, according to the temperature and pressure at which evaporization occurs, so that other characteristics than latent heat have to be taken into account in selecting the refrigerating agent to be used.

The chief considerations are :—

1. The latent heat of the agent when changing from a liquid to a gas.
2. Temperature and pressure at which such a change can be effected.
3. The specific heat of the liquid.

The latent heat of liquid should be high, and its specific heat should be low, compared to its latent heat. The liquifying pressure of the gas at the temperature of the cooling water available should be as low as possible, without sacrificing other requirements. In this State the temperature of cooling water may be as high as 90°, and the temperature of the liquid would be about 10° F. higher. Three examples may be given for 80°, the temperature of ammonia, latent heat at 80 °. 580 B.T.U. temperature of liquid 80° F. Specific heat 1. Temperature evaporation −5° F. 580 − (80° − 5°) × 1 = 505 B.T.U. Refrigerating effect or 12.93 per cent. less.

Carbon Dioxide, Latent Heat 136 B.T.U., temperature liquid 80°. Sp. Heat .98. 136 − (80° − 5°) × 98 = 59.78 B.T.U. Refrigerating effect or 43.9 per cent. less.

Sulphur Dioxide. Latent Heat 176 B.T.U. Temperature liquid 80°. Sp. Heat .4. 176 − (80° − 5°) × .4 = 40.4 Refrigerating effect or 22.9 per cent. less.

This shows that ammonia has the least loss of heat at the expansion valve. The pressure of gas for the above temperature :—

Ammonia at	80° = 154.11 lbs. per square inch.	Weight	0.5291 lbs.
,,	5° = 34.17 lbs ,,	,,	0.1243 lbs.
CO_2	80° = 1,000 lbs. ,,	,,	16.1 lbs.
,,	5° = 342 lbs. ,,	,,	3.853 lbs.
SO_2	80° = 59.612 lbs. ,,	,,	.7586 lbs.
,,	5° = 11.741 lbs. ,,	,,	.1541 lbs.

An examination of the above examples shows that ammonia is the best agent to use from a practical point of view, as the critical temperature for CO_2 is 87.6° F., the latent heat is lost and the pressure high. SO_2 where the pressure is low, it is too low at temperature required in refrigerating work, as it falls below atmospheric pressure, and should air get in it has a very detrimental effect. Other agents are also used, but only to a limited extent. CO_2 is convenient as a smaller compressor is required, and other metals such as brass and copper can be used in construction. As the critical temperature of CO_2 is 87.6° F. at 74 atmosphere and the efficiency as an agent falls off very quickly on approaching that temperature, it is not used to any extent in this state and the field is left to ammonia. Ammonia being the agent chiefly used a description of the compression process is the one chosen for this paper. The ammonia used is anhydrous or should be, and should be guaranteed 99.9 per cent. pure, as any water causes a heavy loss in the efficiency from the characteristic, that one volume of water will absorb the following volumes of ammonia at temperatures given at atmospheric pressures, if pressures are higher the volumes absorbed will be greater.

32°F.	39.2°	50°	60°	70°
1,049.6 Vols	941.9 Vols.	812.8 Vols.	727.2 Vols.	654.0 Vols.

The essential parts of a vapour compression machine are :—

1. Compressor.
2. Condenser.
3. Evaporator or Refrigerator.

The power applied in driving a compression machine at the compressor is accounted for as follows :—

Friction of machinery
Heat rejected during compression and discharge
Heat acquired by the gas passing through the pump
Work expended in discharging the compressed vapour from the pump.

The higher the suction pressure, *i.e.*,,the gas from the evaporator the greater the efficiency of the machine, for while more power is required to compress the greater weight of gas to condenser pressure more thermal unit will be obtained from the power expended than with a low suction pressure.

The amount of heat carried away by the the condensed water is the heat of vaporisation taken up in the refrigerator minus the amount due

to higher pressure and temperature at which liquifaction takes place plus the heat acquired in the pump itself, and less the amount due to the difference between the temperature at which the vapour is liquified and that at which it enters the pump. With these allowances the heat carried away by the cooling water at condenser is the measure of the refrigerating power of any compressor machine. Those machines in which the amount of heat developed in the pump and elsewhere than in the refrigerator is least will give the highest economy in working and consumption of cooling water. Should there be superheating in the compressor the loss amounts to about 6 per cent.

The loss per lb of liquid due to refrigerant evaporating from a liquid to a vapour at the expansion valve between condenser and refrigerator is shown by the formula:

Efficiency = Latent heat × Temperature of liquid − Temperature of evaporation multiplied by specific heat. With say ½ per cent. of water in the ammonia the efficiency will be very much less than shown per lb. of refrigerant passing the expansion valve, and its presence is the cause of many machines not being as efficient as they would be were they circulating pure anhydrous ammonia.

The Linde system of refrigeration being the system the author is connected with, he will now refer to that system. It consists mainly of three parts each of which is designed for each case according to the conditions under which the work has to be done and the purpose for which refrigeration is required.

1st. PUMPS.—The compression pump which continually draws the ammonia gas from the evaporator and delivers it to the condenser, raising it from an inferior pressure to a superior pressure which depends on the temperature of cooling water, and there are three classes of compressors vertical single acting for small plants, horizontal double acting for sizes from 3 tons to 330 tons refrigeration, and compound compressors for tropical conditions. In each case the pump draws the vapour from the refrigerator in a saturated condition, the effect of which is, that no water jacket is required as the heat of compression is taken up by the gas itself so effectively that the compressor will always be found covered with hoar frost when working and the ammonia gas is kept as near its natural condition as is practically possible, and at the same time the curve of compression as shown by the indicator diagrams is nearly an isothermal curve which reduces the power necessary to drive the pump and also the amount of cooling water to condense the vapour. To explain this, if two cylinders are working, one on dry gas and the other on wet or saturated gas, the dry gas will compress along the adiabatic curve and there will be considerable rise in temperature and a hose will have to be played on the cylinder or a water jacket fitted to keep the temperature down to allow lubrication of cylinder etc. The weight of gas drawn into the compressor is less as it is superheated before getting to suction valve. The interior of the cylinder is hot and adds heat to the incoming gas and assists to decrease the weight of gas

taken in. With a wet gas compressor the cylinder is always cold, the temperature of the gas is not raised above about 100° and as no excessive heat is developed in compression, less cooling water is required and a cooler liquid is obtained at the expansion valve. Special arrangements of valves, refrigerator and condensor coils and capacities give this result.

It is of the greatest importance that the clearances in the compressor should be as small as possible so that contents of compressor are completely evacuated and 1-32 of an inch is common practice, the piston rod end in the crosshead being arranged with adjusting screws for this purpose.

On the discharge side of the horizontal compressors is a vessel to intercept any oil that may be carried in from the stuffing box which, if allowed to pass into the coils of condenser and refrigerator would reduce the efficiency by insulating the surfaces inside the coils. The oil from the collector passes to a vessel called the rectifier from which it may be drawn with any water that may be deposited in the collector. The oil can be used again. The rectifier also assists to keep the system clear of water and is a valuable adjunct to a refrigerating machine. The suction and delivery valves are so designed that they may be overhauled or replaced by merely removing a bonnet, the main covers, piston and connecting pipes do not need to be interfered with. With machines above 3-ton capacity bye passes and pump out arrangements are fitted so that any part of the system may be pumped out and ammonia put in any part of the system should necessity arise, either for overhaul or extension.

Owing to the machines being double acting, the strains are equalized. A 50-ton ice machine runs about 65 revolutions, the small sizes up to 140 revolutions. This allows of the steam engines being of small dimensions. The I.H.P. for a 50-ton machine would be only 60. On the discharge side of the machine between compressor, delivery valve and condenser, a check valve is placed so that should any accident occur to the compressor the rush of ammonia from the condenser would be checked. The author knows instances where the end of the compressor has knocked out and it was little short of a miracle the men about the machine did not lose their lives owing to the fact that no check valve had been fitted.

2nd. Condensers.—There are several forms of these, each designed to suit the requirements of the work intended and position where it is to be erected. The principle is always the same. They are submerged, open air, and evaporative. The first generally consists of circular coils contained in a circular tank. The vapour to be condensed enters the coil at the top through a liquid valve. The condensing water enters the tank at the bottom and leaves at the top, ensuring the liquid being cooled to the lowest possible temperature. This style is only used where the supply of water is not restricted and its temperature is fairly low. The water after leaving can be used in the steam condenser for condensing the steam from the steam engine. The chief objections to these condensers is that they are difficult to paint and should a leak occur in the pipe it would

probably escape attention unless the water was tested.

Open Air Condensers.—The coils for these condensers are formed into one straight vertical sheet. In the larger condenser there are generally three separate coils in the sheet and several sheets all connected at top and bottom by manifolds, the space between each pipe being 5-16in. The water is distributed over each set of coils by a slotted pipe, both sides of each tier of coils is effectively exposed to the air and the rise in temperature of cooling water is practically nil, the heat of the vapour inside the coils being taken up by evaporation.

Evaporative Condensers.—These are specially designed for where the supply of water is restricted. They are on the same principle as the open air condenser, but the coils are encased in timber or sheet iron and a strong current of air is driven from bottom to top, which increases the evaporation of water with corresponding increase of efficiency. The loss of water by evaporation for a 50-ton ice machine would be about 500 galls. per hour. Submerged condensers required from twelve to thirteen times the quantity of water more than the evaporative unless the water is re-cooled. Small pipe condensers, *i.e.*, 1 to 1¼″ pipes and coils are made in one length from 80 ft. to 500 ft. without joint by welding. Large pipe condensers, *i.e.*, from 2″ to 2½″ pipe, are built up in sections.

Cooling Towers.—These are extensively used and may be of the usual type where the water is filmed to expose a large surface to the atmosphere, the water circulated over condenser and pumped back over tower or the cooler placed directly over the condenser on a separate floor and the water sprayed by suitable nozzles upwards and is cooled by the evaporation which takes place. Re-cooling arrangements are important in hot climates as the lower the temperature of cooling water the less the condenser pressure and the cooler the liquid the less the loss at expansion valve, and consequently the power required is less and refrigerating effect is increased. In the Linde system the condensed liquid invariably leaves at the bottom of condenser and is carried by a liquid pipe to the expansion valve.

3rd. The refrigerator or evaporator is generally composed of coils of pipes through which the ammonia is evaporated, the outside of the coils being surrounded by brine, where brine is used, or air where the direct expansion system is used. The brine or air being in contact with the coils gives up its heat. There are several methods of applying refrigeration to ice making or the rooms, etc., to be cooled.

In ice making on the can system the brine tank is rectangular. The expansion coils are placed in the tank in rows and completely immersed in brine, and the pans containing the water to be frozen are immersed in the brine between the rows of coils. The ammonia in the coils extracts the heat from the brine and the brine extracts the heat from the water until it becomes frozen solid. To obtain good clear hard ice by this method distilled water must be used or the water must be filtered and agitated by some mechanical means. Without these the ice will be opaque, which has no commercial value as table ice and its lasting properties

are inferior to clear ice, but it is quite suitable for other cooling purposes. In large factories the cans are set in frames, which are constantly moved forward, the motion being rated so that the frame of cans on reaching the end of tank are ready to be lifted out, which is done mechanically. The same lifting gear places the cans in a tank of warm water which loosens the ice and the whole frame is tipped over on a tipping table and the blocks fall out. The mechanical arrangements are so perfect that one man can manipulate the whole and ordinary ice can be made at 3s. 6d. per ton. If clear ice is required the water must be agitated by some mechanical means and there are many methods of doing this. One type has a thin wood paddle which is kept moving in the water. In the Bannister method there is a double-necked bottle, one end being placed in the water, the other connected by a hose to a pipe in which the pressure raises slightly above and slightly below atmospheric pressure. The water is drawn in and forced out of the bottle and the water in the can is kept in constant agitation. The paddles or nozzles must be withdrawn before the ice closes. The brine itself should be kept circulating for uniform temperature.

There are four systems of distributing cold to chambers to be cooled: brine, direct expansion, air passing over or through brine, and air circulated over direct expansion pipes and through the rooms.

BRINE CIRCULATION.—The brine is drawn from the refrigerator by a pump and circulated through coils in the room and returns to the refrigerator, the various temperatures required in the rooms being regulated by the quantity of brine circulated. This is a simple and in some cases an effective way of applying cold, but it is not so economical as direct expansion.

The direct expansion system consists of flat coils of pipes, placed on the ceiling or walls of cold room and in which the gas expands absorbing heat from the air. Each room should have its own expansion and suction valves so as to regulate the temperature. The snow collecting on the pipes by the moisture of the air freezing there should be scraped off to keep the pipes effective. In this case there is no intermediate agent bteween the ammonia and the air of the room, as there is with brine circulation, and a higher suction pressure is obtained which increases the efficiency of the compressor, but it has the disadvantage that there is no storage of cold in the pipes when the machine is stopped. The Linde Company has overcome this by placing a tank containing brine on the wall of the room, and an expansion coil is placed in this which reduces the temperature at the brine and the brine then becomes a cold reservoir which takes up heat during the stoppage of machine.

In both of these methods the circulation of air is not very great, as it depends on the tendency of the air to fall when cold, rise when heated, and the moisture in the air freezes on to the cold surfaces and reduces efficiency by insulating them. However, they are quite effective where freezing is not required.

To increase the speed of chilling and freezing and to keep the air in the

rooms pure and at proper humidity, the Linde Co. has brought out an improvement on each of the foregoing.

The brine is cooled in a shallow tank containing refrigerator coils and on the tank a number of slowly revolving shafts are mounted, each shaft having a number of discs which revolve partly in the brine. The air in the chambers is passed over these discs by a fan and is cooled and moisture deposited and returned to the rooms. In another method on the same principle the air is forced by a fan through a shower of brine passing over a battery of refrigerator pipes reducing the temperature of air and taking up the moisture. Naturally, the brine becomes weak or what is termed sweet, and it has to be reconcentrated, which is done by heating and driving the water off as steam or vapour. Forced air without brine is also used. In this case the surface of coils is extra large and placed in a chamber. The fan drives the air through the coils and through the rooms in the same way as before. If the air is not warm enough to thaw the snow that forms on the pipes the snow is thawed by ammonia vapour, the coils being for the time the condenser.

All these systems are extensively used and each one suitable for its particular work. Brine circulation and direct expansion for the storage of, liquids or goods not affected by moisture or where they are going into direct consumption and only stored for a short time. Forced air is the system now generally adopted for dealing with provisions, fresh meat, or perishable articles, as the importance of dry freezing rooms is becoming more generally recognised. The ease with which temperatures can be controlled by means of air and the distance it can be applied by means of ducts from the refrigerating machinery, are all factors in confirming that opinion and would show that although air machines are becoming obsolete, the application was right and only the temperatures were wrong. To show the great advance made in mechanical refrigeration it may be mentioned that it is now used for very varied purposes, and that without refrigeration to-day, we would be short of many things we now consider necessaries.

The author regrets the rather elementary nature of the paper and the absence of drawings and diagrams, but the time at his disposal is limited, and the subject a large one. His object has been to awaken interest iin a branch of engineering which has done so much for Australia and which is going to do great things for this State.

RAILWAY MAINTENANCE.

By T. Watson.

Railway Maintenance, the subject of this paper, covers such a wide field, that much must be omitted to allow of its being dealt with in a brief essay. That it is proposed to do, by passing by all theories leading up to Railway Construction, and dealing at once and more particularly with some of the every-day duties of a Maintenance Engineer. The subject will be further narrowed down by assuming that the Engineer's work lies on one of the Railways of Western Australia. That being a convenient way of handling the matter besides simplifying after criticism.

A New Railway.

An easy way of entering into the remarks that follow will be to assume that a new Railway has been handed over to the Maintenance of Way Department. Before that is done, the Chief Engineer of that Department will have decided, among other things, what sum he will allow for Maintenance. Be that sum large or small, one of the first things to be done is to organise the Maintenance Gangs.

Flying Gangs.

In this country, it has been found profitable to adopt very largely the Flying Gang System. That is, the cutting up of our Railways into such lengths as will not allow of their being conveniently worked from one centre by one body of men. In that case, the Main Camp will be at or about the centre of the length, with outlying camps to shift to as work lies towards the ends of the length.

Men per Mile.

For the first few years of a Railway's Life, the bulk of the money spent on Maintenance goes on wages. As the annual earnings of a Fettler is easily arrived at, if we divide the earnings of one man into the sum allowed for Maintenance we arrive, roughly, at the number of men we can place on the road. That done, we divide the number of men into the length of the railway and so we arrive at the number of miles that each man will on an average have to maintain. A typical Flying Gang length is 30 miles to which 10 men may be allotted : that is one man to three miles of road.

Balancing Work.

But as some miles are easy to maintain and others more difficult. we have to balance the work, so that Gangers in charge of the more difficult lengths may have as fair a chance of showing good work as those upon the easier.

Grading the Road.

That is done by grading the road, giving more men per mile to the more difficult portions and fewer to the easy, so long as we average out at, our assumed, three miles per man.

Starting a new Gang.

In starting a new lot of men the Ganger will probably be one of the first men on the job. The start recommended by me is, before he does a stroke of work, to send the Ganger over his new length to thoroughly inspect it.

Ganger's Preliminary Inspection of the Road.

His inspection will include things generally, but his particular attention will be directed to the condition of his " Running Top " on which so much of the safety of the Road depends, and on which if faulty so much work will have to be done.

On a form provided for him, the Ganger marks, at intervals of a quarter of a mile his opinion of the " Running Top;" he marks Good, Fair or Bad just as he finds it. From information in our possession it is known whether the Ganger's report is fair or otherwise. If fair, then all concerned start with a clear and clean cut understanding of how things are and what is ahead of them. If the Ganger's report is unfair, we have a quick and ready way of dealing with him.

Starting Work.

As the safety of the Road is the Ganger's first consideration and he is almost certain to have found some weak places on his new length, he would, if left to himself, want to be in half a dozen places at the same time. Indeed with many miles and few men, some Gangers feel overweighted with their sense of responsibility and really do not know what to be at first.

Locating the Day's Work.

Relief comes to them in this way. The Engineer, and the Inspector who is to have charge of it, will also have been over the new Railway, and if their experience tells them that there is nothing so bad but that repairs can stand over for a time, they decide where work shall be started. That done, distinct instructions should be issued that work is to be carried on to a face ; solid work done where work is done at all, and an end put to jumping about in patch-work fashion without method, system, or foresight.

In effect, the Ganger is told to put his thirty miles of Road out of his head and confine his whole efforts and his whole attention to the half-mile or so marked out for him. That finished satisfactorily, he will be given fresh start, probably on the next half-mile ahead.

Questionable Method of Work.

It may be objected that this is a very questionable system of work. But let it be remembered that the Railways of Western Australia differ from those of other countries in many important respects. Besides having light and easy traffic there are outstanding physical differences. We have no mountains. No mountains of the kind carrying snow, that in great measure are responsible for the frequently recurring and disastrous floods of countries like, say, South Western Europe. No overhanging precipices with all their dangers. No treacherous country, sliding hills or floating bogs. Neither ice nor snow. No frosts to make our roads ironbound in winter or to cause up-heaval of track when the thaws come. No anything indeed for the better part of the year but blue skies and sunshine.

Why not then take full advantage of our favourable circumstances? By blocking up some of those channels of expense, by discarding some of those methods of work that not only are prudent but imperative, in countries more rugged than our own, in climates more severe.

The Secret of Keeping Good Work.

The secret of keeping good work is to do everything well. That involves patience on the part of the Engineer and the Inspector: and occasional encouragement to the Ganger, to remove from him the feeling that he is making slow headway. Every man in charge of Railway Maintenance in an easy country like Western Australia would do well to bear in mind these three maxims: (1) Work to a face. (2) Plan out your work. (3) Don't let your plans be departed from.

Where you find a man working on these lines you find one who knows exactly what he wants; whose men know exactly what is expected of them; free entirely from that harassing feeling of being thought capable of doing work in two places at the same time. There is nothing more fatal to real progress than allowing men to shift about from place to place doing a little bit here and a little bit there with just as little to show for their labor.

Running Top

The chief end and aim of good Maintenance is the providing of a safe and easy running surface for rolling stock. In the language of the road "a good Running Top." On new Roads it is not easy at first to keep a good top. If built in dry weather the embankments may be honeycombed with voids. These with the earthworks may settle slowly and steadily. Or suddenly, because of heavy rain, endangering the track. At such times men should patrol the railway to protect possible dangerous places, particular attention being directed to bridge abutments, the earthworks behind which have been known to settle so much as to leave rails and sleepers suspended.

Wear and Tear.

The usual cause of a road becoming faulty is just ordinary wear and tear. The effect of continuous traffic with perhaps strong dry winds or excessive rain. Many miles of road may go faulty about one and the same time. Under such circumstances, some gangers, it left to themselves, can think of no middle course between leaving the road just as it is and tearing it open for great stretches at a time, for what they call " a straight lift ahead." This blind way of opening out is not only very hard on the Fettlers, but it is, as a rule, a sheer waste of money. The more experienced man does a bit of thinking and ends by compromising with circumstances. He understands the value of leaving " well" alone. A touch here and a touch there is all that parts of his road may require ; the heavy task of " opening out " being only done where absolutely necessary. " To save time is to make time." It is by saving time, by avoiding the easily avoidable, not to say unnecessary work that one man hows better results than his neighbours.

Good Material V Bad Material.

Work on the road is assisted or hampered as one is working with good material or bad. Our line of action is, when good, make the best of it. Again when bad make the best of it. Do not excuse yourself or others. Well directed skill and a steady determination to make the best of material none too good, leads not infrequently to gratifying results.

Ballast.

The ballast one has to work with will probably be that of the country the Railway runs through and good or bad one has just to make the best of it.

Rails.

The quality of our rails is not only beyond our control but beyond our judgement. We cannot, by any ordinary inspection we can bring to bear on them, say whether the steel is good or bad. If a few new rails break early under traffic, the Engineer need not be unduly alarmed : they may be the weaklings out of an otherwise splendid lot of rails. The heavier the rail the weaker proportionally it is. The mode of manufacture and the ingredients used is the making of a light rail and a heavy rail may. be exactly the same, the former giving good service while the heavy rail is disappointing. And an almost everyday disappointment and serious cause of anxiety these heavy rails are, where fast and heavy traffic necessitates their use. This difference of quality is due, to the difficulty by the present mode of manufacture, of getting the same amount of work, the same annealing into the heavier sections as is more easily possible with the lighter rails. The evolution of rail making is at present in a very disturbed condition. Good steel can be made. But good steel is not being converted into heavy weight good rails. The recognised

and approved sections of yesterday have failed in practice. The trend to-day is put less metal into the head and more metal into the base and the web, for reasons we would willingly dwell upon if time permitted.

Sleepers.

With one exception, the most important item a Railway Engineer has to deal with is his sleepers. They are the very back-bone of his work. His sleepers are the most expensive item in his track. They are the most expensive item to renew. And although expensive, they are the cheapest and most ready to hand labor saving appliance that he can lay his hands upon. The Jarrah forests of this country supply us with a timber that is the unconcealed, the outspoken envy of less favoured countries. On no other item employed on Railway Construction in Western Australia can money be more profitably spent than on substantial and well cut jarrah sleepers. Well cut means, among other things, timber cut from mature trees free from heartwood. Whoever takes heartwood sleepers, whether from young trees or Crown wood takes trouble and disappointment with them. This phase of the sleeper question and the wider one of future sleeper supplies hardly lies within the scope of this paper. But the Timber Industry of Western Australia, now at an extremely critical stage, would form an interesting and an instructive subject for a paper to be read before and discussed by the Members of the Institute. An easily asked question is. "What are your sleepers costing you?" And equally easy it is to reply. "1s., 1s. 6d. or 2s.," as the case may be. That reply may be true as far as it goes. But it is so far short of the real truth as to be utterly misleading. The cost of a sleeper is not what is paid for it in the bush. Nor is the cost of a sleeper what is paid a contractor to put it into the road. The cost of a sleeper should be measured by the service it gives and in no other way. And that service can be foretold. To put into the ground a freshly cut Jarrah Sleeper containing heartwood is to court failure. On the other hand, to lay down seasoned Jarrah sleepers, cut "off the back," free of heartwood from sound matured trees, is a sure and certain way of laying down material that will last for 20 years and longer: and at the end of their service as sleepers they will be fit for use in many other profitable ways. Without laboring the question further it will be said that sleepers that give short life cost £75 per mile per annum, while sleepers that last for 16 years cost only £10 per mile per annum, and so the price decreases as the age of service increases. Even that is short of the actual truth. For strong lusty sleepers can safely be left to look after themselves, while the weak and the perishing are crying out for help; and help means money with wages at 10s. per man per day.

A diagram was exhibited with the object of shewing how good sleepers were obtained from mature trees, and faulty sleepers, containing heartwood, from immature trees. Also the proper way of cutting sleepers "off the back" and the faulty way of cutting them "on the quarter."

Labor.

Among the many items and articles employed on Railway Maintenance there is one, the most expensive, as it is, speaking broadly, the chief commodity of the world.—Human labor. In Western Australia the custom of the country, assisted by well organised Labor Unions, has forced wages to a high point. It is a common understanding among engineers that, when labor is costly and material is cheap, it is advisable to spend freely on Construction so as to keep down the after wages bill. Cheap work, as we were reminded by our President, in his inaugural address, is not necessarily economical work. And work that is cheap, cheap because construction costs have been pared down, and because of that requires nursing by highly paid wages men is not good business. It means from a Railway point of view, a never ending drag on traffic earnings, a drag that would hardly be felt if its equivalent was paid in the shape of interest on a slightly increased capital cost.

A diagram was here exhibited shewing that of expenditure on Railway Maintenance, about 94 per cent. went on wages and salaries, the remaining 4 per cent. on material. And also figures to support the author's opinion that it was easier and more economical to meet interest on the capital cost of a strong and substantially built Railway, than to pay wages for the heavier repairs and renewals of lighter work. The author ventured the opinion that if 10 in. x 5 in. sleepers were used instead of 8 in. x 4 in., the increased cost for sleepers would be more than met by a decreased wages bill, approximating £8 per mile per annum.

Continuing, the author said with reference to " Light Railways " in a new country of vast extent under rapid agricultural development as in Western Australia to-day, it would be neither fair nor generous to criticise the State's Railway Policy as a question by itself: it is too muchb ound up with other matters. And so it comes that certain essentials to high class Railway construction have to be sacrificed to other interests, on the principal of doing a little wrong to do a greater right. Good reasons can therefore be advanced for the building of cheap railways. But, where easily possible, good reasons should give place to better, as better it would be from an engineering point of view if this country used more freely in the form of Jarrah, what nature has so freely endowed it with, instead of giving our timber away, the pick, the choicest portions of our forests, to any foreigner who sends a ship to Bunbury.

Construction V Maintenance Engineers.

The duties of a Construction Engineer differ from those of the Engineer in Charge of Maintenance principally in that the work of the latter is somewhat of a domestic character. Like that of a housekeeper, whose failure or success rests largely on her method of work, or want of it, on little economies, on the stoppage of leakages and waste. A little saving

here and a little saving there may seem of small importance to the man dealing with large figures. But little things if only enough of them, can assume considerable proportions ; as they can and will do on a great railway system such as ours is, where on labor alone we are paying cloes on to a million pounds per annum.

Check on Leakages and Waste.

Any effective system of check on extravagance or waste should be simple, quick and accurate : easily operated and self contained. That is, all reasonable information should be accessible to the engineer without his having to ask questions. It adds to his strength and influence if he is independent of outside intelligence. Those working under him are quick to detect the Engineer who has not grip and knowledge of what his men have done, what they are doing, and what they are going to do next : spread as they may be, over 600 miles of road.

At any moment on the road or in the office, he may want to know such things as—How is his money going out ? Is he working within his estimates? Are his gangs full-handed ? Whereabouts are they working ? How long have they been there ? When do they shift ahead ? Have they found any faulty sleepers lately ? If yes, where, and how many ? How is that re-sleepering job getting on ? What is it costing ? When will they finish ? And that re-ballasting job ?

These and fifty other things the Engineer wants to know, and know them he can, without asking a question without consulting a file. As we will endeavour to show. Reference here being made to diagrams to follow, which had for their prime object the economy of labor, time and money.

Office Aids : Office Helps.

Dealing first with economy of time. It is a great convenience if there is within easy reach reliable information about matters that crop up in the course of our daily work, It is not only loss of time, but weary work searching old plans and old files for back information. Much of this can be avoided by recording, while incidents are still fresh ,matters that are likely to be wanted now and in after years. This book of diagrams (exhibited) which is open to everybody, is one of our office helps. It shows in concise and easy form information in common request. There are sheets dealing with things in general and sheets dealing with things in particular. Among other matter will be found a brief life and history of our rails and fastenings, our sleepers and our ballast. Particulars of our bridges, our culverts, our gradients and our curves. A record of every broken rail, every main line derailment, every washaway. If we kill a horse or camel, a cow or any smaller stock it is all recorded here : and in such a way that, if further particulars are wanted, one is guided to where they will be found. Such a book

as this enables a certain class of correspondence to be dealt with at a single sitting instead of being put to one side to add perhaps to an already congested office table. More than that. The information contained in these diagrams, being in the possession of others concerned with and dealing with our work, saves an amount of correspondence coming to us that otherwise would be necessary.

Maintenance Expenditure.

A simple diagram was exhibited shewing how, at a glance, the Engineer could see, at fortnightly intervals, how his actual expenditure compared with his estimates. If the diagram shewed unexpected fluctuations no questions are asked, reference being made to the

Fortnightly Expenditure Sheet,

a copy of which was exhibited. It shews the details of each fortnight's expenditure—wages and material—arranged in such a way as to shew easily and quickly where expenditure was under or over normal. If any divergence from normal has to be enquired into, the Engineer can put his finger at once on the item or items on which he wants enlightenment.

Expenditure on General Stores.

It has been already said that any system of check on extravagance or waste should be simple, quick and accurate.

A diagram was here exhibited shewing, in alphabetical order, a list of items of material used on 12 months' ordinary Railway Maintenance. And in parallel columns what each of 25 repairing Gangs, representing 600 miles of Road, had used.

So important to the author is the information contained on his diagram, that each month the returns are entered up with his own hand. The time spent in doing so is well compensated for by the complete check it is on possible extravagance. And also by the insight it gives him into certain little characteristics of individual gangers: which disappear as each is brought into line with the others. For by this diagram, what one careful, steady, reliable ganger uses in the way of stores, is a very fair check on all the others.

Casual Sleeper Renewals.

On a new railway some sleepers decay earlier than others and have to be renewed. A record should be kept of all such renewals so that, as the years pass by, reliable information may be on hand as to the past history of the road. A diagram (exhibited) was recommended as an easy way of recording sleeper renewals. It shewed the year the sleepers were originally laid down, the year that is their age should date from; and also the renewals on every mile, for every year afterwards until they finally have to be renewed to a face, and is referred to as often as sleeper failures and sleeper renewals are being discussed. It dispels doubts and settles

differences of opinion about matters of past years on which memory may easily play one false. A longitudinal section is shown on the diagram so that it can be seen at a glance whether the sleepers are on high and presumably dry ground, or on low lying and perhaps wet country. Some of our railway men attribute the early decay of certain sleepers to their being in low lying, in what they call salt or mineral country. It may be, but the significant and outstanding fact remains that heartwood is at the bottom of it all. Alongside the perished sleepers we find others as sound as a bell, apparently indifferent to their salty surroundings.

Re Sleepering to a Face.

A time comes when it no longer pays to keep patching a road with new sleepers: it has to be done to a face. In coming to a determination diagrams like that referred to in the last paragraph are of great assistance.

As re-sleepering is one of our heaviest items of expense and one we cannot get away from, it is a matter that requires very serious consideration. But some men recommend re-sleepering on very light grounds. For one reason because the money is not coming out of their own pockets; for another, because they may be timid and do not want to imperil their official position; they are taking no risks and recommend early so that responsibility may be shifted on to shoulders higher than their own. These are reasons that no Engineer worthy of the name will allow himself to be influenced by. If he has opinions of his own now is the time to show them. If he is to have the courage of his opinions, when these run counter to those of practical men of great experience, he will do well to fortify himself with reasons on which he may stand secure. Such reasons when founded on sound ,or trustworthy information is conducive, in the author's experience to an easy state of mind.

Examination of old Sleepers in the Road.

His method is to open out 25 sleepers every quarter of a mile, subject them to a close examination and treat the result as a fair sample the samples by the bulk. Rigid and systematic examinations of this kind render an Engineer, in the author's opinion, independent of any man's judgment other than his own.

A diagram was here exhibited showing an examination of the same bit of Road prior to and after re-sleepering. The samples and the bulk closely agreed, which, however, is not always the case.

Re-Sleepering Costs.

Re-sleepering is a costly business. Costs keeping is an important part of an Engineer's duty. The author's practice is to make the output and the cost of every day's work stand by itself. Whether on the ground or a hundred miles away, he wants to know how things are getting along. How many men are employed, where they are working, what he is paying them, what they have done, and what the work is costing.

A diagram exhibited made all this clear, the data for it being compiled at the end of each day's work by the timekeeper. With his up-to-date copy in his pocket, the Engineer steps on the ground a fully informed man, beholden to no one for information: and that the author's experience tells him is a strong position for the Engineer to occupy. If costs are right, material is coming forward as wanted and other things are well, he can leave the work behind him with an easy mind.

Re-Ballasting Costs.

Re-ballasting is another of our costly works on which money can easily leak away. To discover that, if it exists, nothing more effective is known to the author than making each day's work show its own costs. Again that is the timekeeper's business. An up-to-date copy, that is to night, must always be in his possession, open to the works manager and other responsible persons. The re-ballasting diagram, is designed to give useful and necessary information. From it we can tell the number of men employed and what we are paying them. What work they have done and what it is costing. What ballast leaves the pit and where it is spread. The haul or lead in miles and whether the ballast train was fully made use of or not. The point to be noted is that the Engineer again occupies the strong position of being possessed of accurate information. Reasons for this or for that he may have to enquire into, but for information in general he knows as much as if he had lived on the job As regards the cost of work like re-ballasting and re-sleepering, it is the author's practice to be perfectly open with the Inspectors. From the timekeeper, they know from day to day what their own work is costing, and from information in the author's possession, what similar work has cost elsewhere, carried out probably under similar conditions to that in hand. Good managers doing good work are interested in low costs. And it cannot be without interest to them when they know that the cost and quality of their work is being compared and perhaps favorably with that of others.

Work Done on the Road.

Apart from water supply, machinery, buildings, and such like, ordinary fettling is our chief concern: on that the bulk of our money is spent. It is important therefore that we should have easy means of knowing where work has been done, where work is being done, and where work lies ahead of us: in other words, where money has gone and improvements may be looked for, where money is being spent and where it is wanted. A diagram (exhibited) gave this information. It shows the number of days' work put into each mile of road by the fettling gangs. At a glance, one can see when work was last done in any particular locality: and from other sources when required, day, date, nature of and costs of that work. Another diagram showing the fettling costs of each mile of road enables us to focus our attention on any portion of our district.

In a single folio of this book (exhibited) we can see at a glance, 140 miles of our district. It shows the fat years and the lean years of expenditure of every mile: where we lingered and spent money and where we hastened by. If a Maintenance Engineer would make easy work of his duties he must keep a clear head and a tight hand on his finances. This is best done by cultivating the habit of exactness. The author's practice is, first to break up his expenditure allowance into easily assimilated parts and then to gather them together again so that he can view them in perspective, as by his diagram he is able to do.

Quality of Work.

As with his expenditure, so the author is at pains to keep watch on the quality of his work. For that purpose he breaks up his district into divisions of a quarter of a mile, each of which stands alone and is judged alone for all that goes to the making of a perfect railway track. He judges it himself and places a value on the condition of his running top. And similarly he deals with his gauge, cant, ballast, earthworks and waterways. And as his diagrams show, he can tell from year to year, and almost with rigid exactness, whether his work is improving in quality or going back in condition. As he is perfectly frank and open with his Inspectors about their construction costs so he is with his gangers on the condition of their work. Once a year and four times in every mile he puts a value on it. After his inspection, the opinions he has formed are made known to each ganger, in such a way that the latter can see not only how he stands with the Engineer, but how, according to the Engineer's judgment, his work compares with that of other gangers in the district.

Conclusion.

To keep this paper within reasonable limits of time, the subject matter has been hardly more than touched upon. The few points dealt with were designedly selected because, of some of them, they are not dealt with in any railway literature known to the author, and because of others, there is ample room for differences of opinion. In conclusion, it may be said that Maintenance Engineers are, broadly speaking, all working towards the same end. Their practice, however they differ in detail, is based on the same principles. But each of them, according to their individuality, strikes out new roads for himself, employs new methods of work; new roads to be followed or avoided, new methods to be discarded or adopted, as they appear right or wrong in the eyes of others. What one Engineer may do another thinks superfluous. What one man reveals to those associated with him in his work another thinks it better policy to conceal. The author's practice is to carry on the open-door policy of his early training: to conceal, that is, from others nothing that is known to himself, to expect from others a live and intelligent interest in all that concerns their joint work; that, in his opinion, being not only best for the individual but best for the Service to which they belong.

Discussion.

GROWTH OF *ALGÆ* IN RESERVOIRS AND HOW TO TREAT IT.

By J. Faulkner.

Mr. E. A. Mann said, Mr. Faulkner has done considerable public service by drawing attention to the Copper Sulphate method of purifying water, as it is, I think, peculiarly adaptable to the conditions existing in this State. The first serious study of the effect of *Algæ* took place about the year 1875, and it is extraordinary how wide-spread are the disagreeable effects of this form of plant life in relation to water supplies. It was not until biology had become developed into a recognised science that the study of this form of life became at all possible, but in more recent years it became pretty evident that most of the instances of disagreeable taste and smell in reservoirs are due to their growth French, German and American investigators have all been at work in the endeavour to combat this evil, but as far as I can ascertain, the most complete study of this subject has taken place in America, where the first tests with copper Sulphate were made about the year 1901. In 1904 the Government pamphlet was issued (Bulletin No. 64, Bureau of Plant Industry, U.S. Department of Agriculture) entitled "Method of Destroying or preventing the growth of *Algæ* and certain Pathogenic Bacteria in Water Supplies." by Moore and Kellerman, to which I am profusely indebted for information on this subject. The importance of a cheap and easy means of destroying this pest will be recognised when it is remembered that prior to the introduction of copper sulpate the only means of improving a contaminated water supply was by such expensive means as covering the entire reservoir, substituting gravel for earth bottoms, removing all decaying organic matter, and other equally troublesome measures. Moore and Kellerman show the toxic quantities of copper sulphate for the various forms of lower life are as follows:—Paramoecium and Amoeba, one part in one million, Crustacea, one in ten thousand, Mosquito Larvae, one in ten thousand to one in two hundred thousand; and the principal objection which they had to raise against the use of copper sulphate was that it might have poisonous effects on human beings using the water, but that this objection has very little foundation can be gathered from the following facts:—There is no doubt that the power of copper salts as poisons has been greatly over-rated, so much so that in some countries where the use of copper for greening preserved vegetables was once prohibited the prohibition has now been removed, and extensive experiments have shown that the soluble salts of copper can be given up to as much as one gram (15½ grains) per day. Of course it is better that this quantity should not be taken continuously, but it

would appear that a safe quantity for continuous daily absorption would be .02 of a gram. Now if copper sulphate is added to water in the proportion of one part in a million, in order that a person could absorb .02 of a gram it would be necessary for him to drink over forty quarts daily. This is supposing that the whole of the copper added to the water remained in solution, but as a matter of fact it is not so, most of the copper which is added is precipitated. No trace of copper has been found after twenty-four hours in a reservoir to which it had been added in the proportion of one part in one million, though it is considered possible by delicate chemical means to detect one part in fifty thousand. Some of the copper is precipitated in the filaments of the *algæ* and some is thrown out of solution by the salts dissolved in the water. This was so in a marked degree in the water at Mount Eliza treated by Mr. Faulkner. As the water streamed away from the bag containing crystals of copper sulphate it possessed a slight blue cloudiness due to finely precipitated copper salts thrown out by the chemical action of the alkali in the bore water. It has been proved that this does not detract from the value of the treatment since the precipitated carbonate, hydrate and phosphate of copper are toxic when in contact with *algæ*. Rather is this precipitation an advantage for it is more likely that the excess of copper instead of passing into the mains is thus thrown down with the sludge in the settling tanks and reservoirs and is thus removed. This must have been the case in the Perth Supply, as I have been unable to detect copper in any of the water treated by Mr. Faulkner. Moore and Kellerman give a large number of tests with different strengths of copper sulphate upon various kinds of bacteria. The solutions used vary in strength from one part in one million to one part in fifty millions, and the following figures, taken from their pamphlet, show in a remarkable degree the effect of a solution of one in four million upon the filaments of Anabaena, one of the most troublesome of the water *algæ* The treatment was made on July 9, and the following show the number of filaments found in the water before and after treatment :—July 6.3,400 ; July 10.54 ; July 11. 8 ; July 13.0 ; July 15.0 ; July 20 0 Filaments per cub. cm.

This is the same strength as the solution used by Mr. Faulkner, one in four million, which, as he has already said, only cost 1s. per million gallons. It has also been found that instead of using sulphate of copper in solution copper plates suspended in the water will have a marked effect but this is not easily applicable to our reservoir unless copper plates were suspended in the intake to come in contact with the water as it flowed in. Dragging bags containing sulphate of copper crystals over the surface of the reservoir is as cheap and easy a method of treatment as any available. That copper plates, however, do have an effect where sufficient area of copper can be brought into contact with the water is undoubted, as it has been found that water containing cholera germs after standing for six or eight hours in a copper vessel has been perfectly safe to use. This might be of immense value in tropical and eastern

countries. The use of copper sulphate, however, need not be confined to the destruction of *algæ*. Kellerman and Moore say that it has a distinctly toxic effect on mosquito larvae, both directly and indirectly by destroying the bacteria on which they feed, and this, with the growing knowledge of the effect of mosquitos on the spread of disease will doubtless lead in time to the extensive use of this method of combating their increase. With regard to pathogenic or disease producing bacteria, such as those of typhoid, copper sulphate is also of value. Experiments have been made which show that at ordinary temperatures a solution of one part in one hundred thousand will kill typhoid and cholera germs in three or four hours, and I feel strongly of the opinion that this affords a method of treatment peculiarly applicable to the conditions existing in the out back districts on our goldfields, in the clay pans, dams and reservoirs constructed all over the country for the conservation of water derived from surface catchment. There is always a certain amount of danger from the collection of disease germs, and though it seems pretty evident that most of these germs are incapable of existing for any length of time in water supplies of this character, yet where the conditions of catchment give rise to the accumulation of organic matter, or where the water is used at a short interval after collection, it would be found of distinct value to have a method of treatment which would ensure the destruction of pathogenic germs. It would seem that such a method is here available. It does not appear desirable, however, with all its advantages, that copper sulphate should be used to replace the recognised methods of water filtration and purification where such is available, and it is also advisable that it should only be used under trained advice. The conditions under which Mr. Faulkner worked are of course somewhat different to those mentioned by the American investigators, who mainly applied the treatment to storage reservoirs. Mr. Faulkner says that the growth of *algæ* was only inhibited for one week, but of course he was practically working in running water, and hence his conditions were about as unfavourable as they could be for the trial of the method. In America instances are quoted where reservoirs have been kept free from *algæ* growth by being treated only twice a year. Mr. Faulkner's results are therefore the more satisfactory, and under similar circumstances his method of washing the concrete walls of the reservoir with the solution would appear to be one peculiarly worthy of attention. His difficulty was the greater because of the extremely favourable conditions present in the nature and temperature of the water itself for the growth of these plants, and it is very gra ifying to know that the intolerable state and smell perceivable in the Perth Water Supply during 1907 and 1908, and which was a grave cause of the necessity to thus deal with the water supply, as well as of inconvenience to the public, have been entirely removed. I believe that the method is now being used also in the Eastern States. and I heard recently that it was being applied in Sydney with complete success. I have, however, no details as to the treatment they employed,

Mr. H. T. HAYNES said, in common I am sure with others present there are one or two points upon which I should be glad to have a little further light. The author points out that since the water from the Redan Street bore has been in use the growth of *algæ* in the service reservoir in King's Park has developed, but he does not express any opinion as to its cause though he does suggest it is due to some extent at least to the temperature of the water. It would be of interest to know whether he thinks the locality of the bore and the strata through which it passes has any bearing upon the phenomena, what also may be the depth of the bore. In the last paragraph of the paper reference is made to the fact that of the six bores from which the town supply is taken not more than three of these will promote the growth. In order to make the paper complete and fully informative it might be well to state the relative positions of each of the bores indicating those of each class. I refer to this on the grounds that every effect has its cause and there must be some reason why the water from some of the bores promotes the growth and others do not and this experience is of much value to the profession. I observed a short while back a reference in the *Engineering Record*, March 5, 1910, page 277 to *algæ* growths found in covered reservoirs and the statement made, was that when water pumped by compressed air was introduced the growths appeared but they disappeared when the compressed air system was discontinued. The question which this suggests to my mind is—is the growth of *algæ* in the King's Park reservoir due to the same cause and if so does it arise from the temperature alone or from the impregnation ? so to speak—of the water by the air. Another rather interesting phase of the question is the effect of *algæ* upon the organic matter contained in the water. Dr. Percy Frankland, Professor of Chemistry in Mason College ,Birmingham, in a paper on bacterial purification of water, observes that while "there is but little direct experimental evidence" on the question, the fact that *algæ* may and do cause a marked reduction of organic matter in water has been stated by many experimenters. Pfeiffer and Eisenlohr found *algæ* always abundantly present in the River Iser in those places where the organic matter was large. Thus in those parts of the river below Munich in which the polution of the stream was marked, *algæ* was conspicious, whilst above the city, before the stream had suffered contamination as well as lower down after the stream had undergone 'self purification' no *algæ* could be detected. In this connection it would be interesting to know the degree of organic purity of the water said to be the cause of *algæ* growths in the King's Park reservoir. Then as to the effect of *algæ* upon bacteria, it seems that these cannot exist well together. Dr. Reinsch of Altona has stated that in the summer of 1894 several filters of the Altona water works containing unfiltered water above the sand had become quite green in consequence of the excessive quantity of *algæ* present, In other filters, no *algæ* was present. The water which was free from *algæ* contained exactly 5 times as many bacteria as that in which they were present. Regarding the

method introduced by the author for treating the water, it is novel, and seems to deal with the nuisance, just at the right place the peculiarity of the growth is that it must fasten on to something and does not appear to grow beyond the influence of light in this case. In dealing with a similar complaint in the service reservoirs of the Baltimore water supply, copper sulphate in the proportion of 1 part to 6½ millions parts by weight was applied by towing bags containing the required quantity by boat over the surface of the reservoirs,. Analysis showed that at the end of 48 hours there was a great reduction and a complete disappearance at the expiration of 120 hours after application. The capacity of the reservoirs was 220 and 416 million gallons respectively. At the end of 24 hours analysis failed to discover any trace of copper in the water.

Mr. W. LESLIE said in view of the few days required for the growth of the *algæ* and of the fact that they do not appear in Victoria Reservoir, I would like to ask Mr. Faulkner whether it may not be probable that the growth of these in the service reservoir is due entirely to the introduction of bore water into that reservoir? It is well known that these plants are nourished by the absorption of mineral and organic matters in solution, in the water itself, and the presence of *algæ* is so much evidence that some purification of the water has taken place by natural means and each plant represents a certain quantity of mineral and organic matter formerly polluting the water, changed by natural means into an innocuous form. Since 1904 when the United States Government Department of Agriculture published, in their bulletin No. 64, an article by Messrs. Moore and Kellerman on the effect of the use of sulphate of copper, upon *algæ* and other microscopic organisms, its use for this purpose has spread very much, but it is now, I think, generally recognised as only a temporary method of getting rid of one objection by concealing a greater one, which is open to grave objection. Mr. Clemence, M.I., Mech., E. in an article which he lately published on the "Treatment of Water Antecedent to Filtration" puts the matter very concisely; he says "Ths growth of *algæ* is only the conversion of one chemical form to another and that therefore the use of copper sulphate may cause the rapid disappearance of a trouble existing in the form of a mass of *algæ*, but at the same time it liberates a quantity of mineral and organic matters in the form of solutions which must be removed before the water can again be considered pure." Messrs. Puech and Chabal have given considerable attention to this in the design of their filters, and before the water is admitted to their fine filters it is introduced into a pre-filter of coarse sand, placed between the gravel filters, where the bacterial filtration takes place. I cannot therefore say I agree with Mr. Faulkner that the principal objections to the use of bore water are, or can be, overcome by the use of sulphate of copper treatment. They are only, in my opinion the more completely hidden.

In reply Mr. FAULKNER said: Mr. Haynes asks for information as to the predisposing causes of the growth of the *algæ*, also the locality of

the bore, and if the strata it passes through has anything to do with the growth. I cannot answer these questions in a satisfactory manner unless I go back to the time we first commenced to use the water from the Redan Street bore. I was aware of the fact that the temperature of the water from the bore in question was 100 F., for too hot to pump into the reticulating pipes (even had there been any of sufficient size to take the water) I had therefore to construct a scheme so that the water delivered into cooling channels in a concrete tank that was open to the sunlight. Within twenty-four hours of the advent of this water, the bottom of the channels were spotted green very thickly, in forty-eight hours there was a thick growth of *algæ* in shape like button mushrooms, but a beautiful green color. These arrived at maturity in about four days, and then commenced to decompose rapidly, giving off a very strong smell and an earthy taste to the water. I am of opinion that the origin of this *algæ* was from the swamps about Leederville, where I believe it used to flourish when the temperature of this country was probably never less than 100 deg. in the shade, that as the temperature gradually decreased, the *algæ* died, leaving its spores. I have not heard of any of this *algæ* being seen about the country in the soil this was washed in various clefts in the earth. Through one of these deposits the Redan Street Bore was driven, the spores came up with the water and germinated in the tank at King's Park. It requires a high temperature and sunlight and thec sulphates in the water provide nutriment, as when the *algæ* decomposes it gives off a strong smell of sulphurated hydrogen. I am aware that some persons think that the spores are air borne, but if this was true, about one species, it would most likely be true about 50 per cent. of them, and then we should have had at least ten or twenty different plants of the same family growing at once, whereas there was only one, and as we cannot have the plant without the seed so we cannot have the latter without the plant, and I cannot hear that anyone has ever seen any.

The tank was roofed in, and this particular species has not since shewn up, what we have been troubled with since, comes from the Victoria Reservoir. The depth of the Redan Street Bore is 1,760 feet.

Discussion.

ADHESION BETWEEN CONCRETE AND STEEL BARS.

BY F. W. LAWSON.

Mr. WILLIAM LESLIE said: The only fault which I have got to find with Mr. Lawson's excellent paper is that it does not go nearly far enough. The tests made, while excellent in themselves, are I submit much too few on which to build formulae for general use. The general practice to-day for re-inforced work is I believe to allow, for frictional contract, 100 lbs. per square inch of surface area for indented bars, and 70 to 75 lbs. for plain bars and many important works have been satisfactorily completed on this basis. This is much higher than Mr. Lawson's formula would allow, with a fair factor of safety, particularly in the case of the plain bars. I cannot help thinking there must have been something wrong with that No. 1 specimen, where the bar drew out with only 69 lbs. per square inch of surface contact. I believe the concrete must have been too dry or not have had its fair share of cement mortar. I am thoroughly in accord with Mr. Lawson in the matter of the size of the stone used in these tests, and I further think that to get the best results the size of the stone should bear some proportion to the size of the re-inforcement, I think in no case should the size of the stone exceed twice the diameter of the round bars used in re-inforcement, or the sum of two sides of a square bar, with a maximum size of stone of $1\frac{1}{4}$ inches for any size of bars. A matter on which I should like some information is the amount of water used in mixing the concrete in these tests. I think there is a tendency to use too little water where the concrete for re-inforcement work is to be placed in forms, on account of the pressure which is then liable to be put on to the forms. Concrete for re-inforcement work should be mixed to the consistency of well tempered mortar, great care being taken to remove any accumulation of *laitence*, where the work is joined.

Another matter which I should have liked to have seen dealt with, is the best depth for re-inforcing bars from the surface. I think for small bars, about three times the diameter of the bar from the surface, and for large bars twice the diameter is about average practice, but I find there are very great deviations in this respect.

Mr. F. W. LAWSON said: In replying to the remarks of Messrs. Leslie, Oldham, Haynes and Breganzer, I desire to put before the members sample of the type of Indented Bar used; and, as Mr. Oldham rightly pointed out, the bond in this type of bar is of a mechanical nature rather than of an adhesive nature. Regarding the question of the size of the

metal used in concrete blocks made, I am in accord with Mr. Leslie in reaard to the advantages of small gauge matrix, but would not in practice go as far as he does in using a maximum size of 1¼″. I personally favour ¾″ as the most useful working size for reinforced concrete, any larger size stone is likely to make it difficult to obtain the dense mass of concrete, so desirable where reinforcement is used. In this respect there can I think, be no two opinions that excessive ramming is most undesirable and this leads up to Mr. Leslie's question as to the amount of water used, and although no records were kept as to the quantity per cubic yard yet I have no hesitation in saying that the concrete used could fairly be classed as being mixed with an excess rather than a deficiency of water. So much so was this that practically no ramming was done to the blocks, rather the process was cutting with a pointed instrument to bring the mortar fairly up to the faces. In regard to No. 1 specimen, I was aware before the tests were made that this bar was not so rigidly fixed in the block as the others, as the concrete had broken away and a slight shake was noticeable. However, as probably the same conditions may happen in practical work, it was thought advisable to let this sample take its course. Mr. Breganzer has drawn attention to the use of barbed fencing wire as a reinforcement, and there is no doubt that the work (Coolgardie tank), brought before the members, illustrates the advantages to be derived by having steel so designed as to give mechanical as well as an adhesive bond. In conclusion I would like to add that, by the kindness of the Engineer-in-Chief and the Engineer for Water Supply and Sewerage, I have had the opportunity to make further tests, and have used varying sizes of metal with a result that such tests, as given in my paper, have been confirmed. The average adhesive between round and square bars and concrete is about 208 lb. per square inch, and that for indented bars 478 lb. I hope at some future time that the detailed results of the latter experiments will be available for the Members of this Institution.

(NOTE.—See diagram at end of book.)

Discussion.

REFRIGERATING MACHINERY.

By J. W. Henderson.

In reply to Mr. Cairns Mr. John W. Henderson said: 1st The efficiency of refrigerating machinery depends on the quality of agent used. 2nd. Compressor. The effective displacement and condition of gas entering the compressor. 3rd. The temperature of condensing water as it leaves the liquid or bottom end of condensor has also a very marked influence on the efficiency of compressor. Indicator diagrams are very necessary to ascertain the condition of the compressors, their pistons, valves, to show how the agent used is being displaced and with a theoretical knowledge of the agent used better practice will be obtained.

The application of refrigerating machinery to the smelting of iron effected the following saving as shown by Mr. Gayley in 1905., where it was applied to Carnegie Steel Co., Etna, P. A. America. Blowing Engine, 2,700 H.P. saving 152 H.P.; reduction in coke used 20 per cent.; Increased output of iron, 25 per cent. The application in this case was to reduce the amount of water in the air entering the furnace and to enable constant grade of iron being produced.

Refrigerating machinery has also been used to cool rooms in hot weather and heat them in cool weather. The amount of fuel used is about 25 per cent. less for heating, when used with this application than it would be with stoves or hot water service. In this State it would not show the saving indicated. The condenser coils and refrigerating coils are reversed for each effect.

In reply to questions by Mr. H. T. Haynes Mr. Henderson said that Mr. Haynes enquiry whether refrigeration had been used for sinking shafts for sewage works. The first application I can find any trace of was in 1883 by Poetsch and to describe it would require a paper and diagrams by itself. It has been used for sinking shafts in wet treacherous country, but I am not aware it has been used in Australia. The object is to form an ice cylinder round the shaft to be sunk of sufficient strength to give support to the shaft put down until it is completed. The amount of mineral matter in solution in the water has also to be considered. The application is by brine magnesiam chloride (28 per cent. solution). The pipes which must be put down vertically with great care and are double pipes, i.e. one external and one internal. The cold brine going down the internal pipe the external pipe returning brine to the refrigerator.

The distance apart and diameter of pipes depends on the diameter of shaft and depth to be sunk. For small depths the pipes should be spaced from 2″ to 3″ according to the diameter of shaft required. The diameter of external pipes from 2½″ to 5″ . The time required for freezing is from 4 to 10 months. As I have said before the amount of mineral matter i.e., salts in solution would have to be taken into consideration. The greatest depth I have heard or read of is about 500 ft. To make an estimate of cost the following information would be required. 1st. Diameter and and depth of shaft required. 2nd. Nature of country and density of water. Generally speaking the amount of refrigeration required reduces itself to the amount of ice required, to give support to the shaft put down. I would have been pleased to give Mr. Haynes a better reply, and to give him further information but each case must be considered by itself and would probably require seperate treatment. I can only therefore indicate the general application. There are instances where refrigeration has been used for this purpose that have overcome difficulties which engineers would not care to undertake without its aid.

Discussion.

MUNICIPAL ENGINEERING.

By H. T. Haynes.

Mr. T. Paterson said: Mr. Haynes says "the question of grading is governed largely by existing buildings." This is a point which is so overlooked by our friend the "man in the street," who perhaps if he realised the difficulties which attend the improvement of levels of certain of the older streets, would not be heard quite so often. In numbers of cases in which the engineer is called upon to construct roads, the street is so built upon that it is practically necessary to build the whole road with a sidelong fall, making one kerb higher than the other, and it will be seen that this necessitates having a crossfall steep on one side and flat on the other side of the roadway, or having the crown to one side of the centre and using uniform cross falls. The latter way of dealing with these roads is the best in my opinion, as on it the traffic will be fairly uniformly distributed, while on a road having one side steep and one side flat the traffic will be almost exclusively upon the flat part and the consequent wear exaggerates the original disadvantage as to drainage under which this side commences life. For my own convenience I use a diagram which shows the distance between the crown of the road for different differences in level of kerb and different cross falls. Again Mr. Haynes states: "The cross fall of a road should not be more than 1 : 24". I cannot agree with this as a general statement, although I consider that for longitudinal grades up to say one in 50 this is an ideal cross fall, yet as the grades become steeper than this, it will be necessary to increase the cross fall to ensure of the water being rapidly thrown into the channels, and so prevent scour as far as possible. In this connection Judson says "the crown for macadam is increased as the slope increases; half-inch per foot being usual on level grades, and a maximum of three-quarter inch per foot on steep slopes, increasing to one inch on excessive slopes." I would be glad to hear Mr. Haynes opinion as to the relative value of street watering by day and by night. In my opinion the watering should be done at night, and last year's experience with the city watering very strongly bears out this contention. During the first part of the year the watering was done during the day time, with the result that the metalled roads got very much out of repair, and were becoming worse daily, and frequent complaints were received of the loose metal which soon covered many of the streets. Later the time of watering of all but the centre of the city was altered and the work done at night, and immediately the roads began to improve, and were very soon back in their usual condition, There was also a noticeable decrease in dust from the time that night

watering commenced, but I would not care to definitely attribute this to the change in watering on one year's experience, as other conditions may have entered into the question.

Mr. H. C. CASTILLA said: My first connection with road construction commenced some 31 years ago in the North of Scotland. I was engaged at that time in the surveying and construction of mountain roads, one, notably, through the forest of Invercauld, was at the time, and may be for aught I know, still, the highest carriage road in the United Kingdom. The district in question may be described as a monument to road construction. There existed the old Roman roads, and still more notably the roads constructed by General Wade during the subjugation of the Highlands after the Jacobite Rebellion of 1745. Following on were roads personally engineered by Telford, and others subsequently on the McAdam model. The Roman roads are simply causeways constructed regardless of expense, but as they were carried out practically by slave labor, this was a matter of little consideration to them. Those constructed by General Wade can only be described as a pavement of huge cobblestones. They were looked upon at the time as a monument of engineering skill, and to use the words of an Irfsh Engineer Officer engaged on their construction—the quotation is somewhere in one of Scott's novels—"Had you seen these roads before they were made you would have held up your hands and blessed General Wade." Of course these roads are not to-day in use, being largely off the line of traffic, but are stili in evidence. Of the Telford and McAdam model they exist everywhere and are scarcely distinguishable one from the other. When I came to this country first, some 24 years ago, I could not help being struck with the resemblence of the roads—I am speaking of course of the country roads—to those of General Wade. The bigger the stone the better it was liked, and to travel on an average Western Australian road at the time and about Perth was a tribulation. The Telford model was being adopted, in Perth and Fremantle. When I became City Surveyor of Perth, some 19 years ago I was disagreed with for tearing up some of these cobblestone roads, and converting them into what might be termed McAdam. At the outset of my term of office I was confronted with the question of width of road. There seemed to be no logical system, and I took up the stand at the outset that no road should be less than of such width as to admit of two vehicles passing each other comfortably. Many roads were 12 ft. wide. This to my mind, was useless extravagance, as a 12 ft. road is a one vehicle road, and it need not have been more than 8 ft. I therefore advocated a multiple of 8 ft. in the construction of our roads, then the main streets of the City. I should have course have preferred to advocate the construction of the full width of the street between footpath and footpath, but there were two insuperable obstacles to this, one, the lack of funds, and the other, lack of drainage. Leaving a space of sand between the road and the footway was the only means of preventing flood. The

question then arose as to the thickness of these roads. My observations had led me to the conclusion that, after providing a foundation on sand which would carry the heaviest weight possible to bring to bear on it, there should be protecting metals, such as bluestone, to such a thickness as would allow a reasonable margin between the foundation proper and the surface. I found the breaking down of the old cobblestone roads into about 3″ and 4″ metal made all the foundations requisite, blue metal then being applied in layers as required as a protective against friction. Caution compelled me to commence with a thicker road than I afterwards adopted, 12″ being the depth with which construction was commenced, to wit, 7″ of limestone, 3″ of large gauge bluestone, 2″ of small gauge, the whole being dressed with a thin layer of bluestone grit, each layer being thoroughly rolled and watered. Further experiments converted me into the use of good ironstone gravel as a foundation road. I found that 4″ of well consolidated gravel would carry the very heaviest traffic brought to bear on it. I do not advocate this as a complete road, as of course there is no margin for wear and tear, but it is adequate for a foundation, and serves the very important purpose of completely subjugating the disintegrating sand. One notable instance I may mention. Barrack street, from Hay street to Wellington street, had to be reconstructed. Barrack street consisted—I mean the roadway proper—of a 24 ft. wide cobblestone road. I had the footways and gutters constructed, and using the outer gutter kerb as a template, proceeded to construct the road from gutter to gutter. The kerb in question was of timber 9″ deep. The cobblestones served, after being broken up, to form a layer of about 5″ thick when rolled. It was then my intention to have commenced utilising the blue metal on top of this when an untoward incident occured. The wells at the quarries gave out, and the supply of blue metal for the City ceased. I was in a dilemma; footpaths and waterchannels were constructed, and a mass of limestone metal extended from channel to channel. There was nothing for it but to adopt a temporary expedient until blue metal became available. I therefore spread a layer of about 1″ of ironstone gravel on top of the limestone. You can imagine the curious appearance the street presented, water channels standing some 4″ above the roadway proper. Luckily this was in summer, and the water channels were not required. I was in fear and trembling that my 5″ road would break through, as it had been subjected to the heaviest traffic in the State. Practically, however, no impression was made on it until such time as the blue metal .w.s available. When this became available there was much grumbling over the temporary roughness of the road which had hitherto been so conveniently smooth. I may state that the late Mr. C. Y. O'Connor, Engineer-in-Chief, evinced a keen interest in these operations. He was inclined at first to be quizzical at the unfinished state of the road, but when completed I was struck with the fact that the method in question was incorporated in the Public Worke Dspartment specifications. You will observe this road never was more than

9″ thick. Some years after, when it was broken up for blocking, I carefully examined it and found that it had worn down to as little as 5″ without breaking through. On my relinquishing office a new method was adopted, it being deemed necessary then to construct roads up to 2 ft. thick, an extravagance which, in the face of previous experience, I unhesitatingly condemn. In all metalled roads the secret of longevity is maintenance. After a road wears 2″ or 3″ it loses its utility in many respects, becoming rough, uncomfortable, and expensive to vehicular traffic. On the subject of road watering I have formed mixed ideas. Watering I think should not be brought into use more than possible as a factor of maintenance. I think tar when inexpensive should be largely used, but I do not profess to have authority in this question.

In reply Mr. HAYNES said: In answer to the remarks by Mr. Hume the period of the year when the work can best be undertaken depends amongst other things on the nature of the work. Thus ordinary macadam roads are best undertaken in the Australian climate during the rainy season because under such conditions a more rapid binding results and with the conveniences a town has for obtaining supplies of material very little if any extra cost is entailed. In country districts it is advisable to obtain and store the necessary material during the dry season for use later on. With tar macadam construction the authors 'opinion is that the better period of the year is just after the rainy season has finally closed or before very hot weather sets in. As pointed out in the paper such work cannot be successfully done in the presence of damp or wet surroundings. Work in which tar is a constituent is likely to be injured it done during very hot weather. Cool dry weather is undoubtedly the better condition. The question of supply of labor does not enter to any material extent into the relative cost of municipal work in this country for the reason that whether the supply be full or scarce the rate of wage does not vary. In country districts this of course may be different. One cannot but agree with Mr. Hume that too much information cannot be kept as to the circumstances under which each piece of work is done if comparative statements of cost are to be of real value and it is herein that many of the text books are deficient. The author is indebted to Mr. Hume for the valuable information he has supplied with regard to timber. Jarrah and Salmon gum—The data given certainly points to the conclusion that Salmon gum is very suitable for wood paving and it would be of value to know in what degree it is liable to dry rot and its natural contraction and expansion under the influentes of wet and dry to which in a road it would be subject. The matter of street watering is dealt with in this paper. Mr. Paterson referred to the difficulty of dealing with roads where buildings are already erected on both sides and at apprecibly different levels. The author admits this is a real difficulty and agrees with Mr. Paterson that it is better to bring the crown out of the longitudinal centre and thus give a uniform cross fall from crown to channels than to preserve the crown in the centre. The diagram furnished

by Mr. Paterson is very convenient for determining the position of the crown. With regard to the relative values of day and night watering the author is of opinion that for maintenance purposes night watering is of very much greater value than day for the reason that with the lower night temperature the evaporation is much less and the penetration consequently more. And, moreover, the absence of traffic at night allows the binding to become more efficient. This is more apparent on ironstone gravel roads than on any other, and further, the night watering allays the dust to a greater degree than day watering and by cooling the road surface imparts a freshness which those having to use the reads in early morning have not failed to recognised. Mr. Leslie's difficulties with regard to the varying results achieved in the use of tar macadam are common to all who use it. The success of laying St. George's Terrace may be due to some extent to the fact that the workmen engaged on it knew nothing whatever about it, but did just as they were told, while after a little experience workmen have a tendency to attempt an improvement of the engineer's methods though without the engineer's consent or knowledge. There can be no doubt but that we require to know more of the physical and chemical properties of tar—it is very noticable that upon stone coated with hot tar and heaped for about three weeks a soft and very adhesive coating forms—but if too much tar is applied it acts as a lubricant and instead of binding the stone, has a tendency to assist its movement under the influence of traffic. Then it is essential that the stone shall be cubical in form and be very closely compacted and finally receive a coating of tar and dry stone chips. Constructors may be sure that any variations in the conditions will produce variation in the results, hence every process in tar macadam work must be closely watched.

Discussion.

MIDLAND JUNCTION WORKSHOPS MACHINERY.

By E. S. Hume.

Mr. Lawson referred to the many good points raised by the paper in the way of effecting economies in the workshops and running practice. He particularly mentioned the fusible plug for boilers. In reference to the innovation of the wood top board for trucks this not only saved upkeep of renewal of boards and iron strips but also the tarpaulins and prevented goods belonging to the public from being injured by being drawn over loose screws and bolts.

Mr. H. T. Haynes in speaking of the alteration of the top board of trucks in a very appreciative manner, asked Mr. Hume if it were not possible to have some alteration made to prevent flooring boards of ballast trucks from being forced out of position by the timber swelling by wet and opening out in summer through heat.

Mr. A. D. Cairns in speaking asked which system of apprenticeship would Mr. Hume advocate to produce the best men for the rank and file of his industry; the old system whereby a boy left school at 12 to 14, served a turn at various machines, and in different departments, and finished up as a fitter or erector of machinery; or the present day methods whereby the rank and file are made specialists of one or a very few machines: are the latter as good all round mechanics for the Australian needs as the old time millwright? B. What proportion approximately of tradesmen at present under his charge learned their trade in Australia, and how do they compare with the imported Arti cer? C. Does it pay to wash waste when you can buy good waste at 35s. per cwt.? Are the residues recovered in oil reliable for lubrication or metal cutting, and can they be produced free from dirt, objectionable decomposition, or chemical change that would affect the work they were used upon? D. Could any vehicle constructed under the author's charge be specially set apart or recommended by him for the carrying of our fruit in an efficient manner, requirements being ' light tightness," ventilation by slots across the floor for the heavy gases of fruit to get away, a little ventilation on the top for the lighter gases generated by the heat also to get away; of sufficient thickness of construction all round to prevent an undue rise of temperature, " heating," or premature ripening of the fruit. This is assuming that ice cooled trucks are prohibited in the cost for the average grower. E. Would the author recommend the weighing of double bogey trucks say, up to 24 tons, on a 12 ton weighbridge, one

end at a time. Could accuracy be expected from the ordinary Avery weighbridge by this two stage method anywhere approaching the accuracy obtained by weighing locomotive wheel loads individually at the workshops? In asking these apprenticeship questions due regard has been given to modern practice, and the trend of American and German technical pretensions in this respect. A great deal of Foster Fraser nonsense has been broadcast about the inefficiency of British and therefore Australian methods with a total disregard to the basic facts. Great Britain's industrial supremacy is traceable to Trade guilds and methods of imparting skill to the young mechanics while both Germany and America were and are imitators of work originated by British brains under these methods. Is it possible under the new order of specialization, centralizati n and new machines as seen at Midland that the handicraft of the rank and file can be maintained in a country like Australia, where a great deal more machinery is imported than is manufactured, and the men in charge of the plants seldom see a workshop after their apprenticeship is finished: Is the new method as good as the old for making men that could man an industry or a Navy? And is Western Australia offering sufficient facilities to make good all round mechanics from the State school boys.

Mr. E. S. Hume in reply said that he was pleased that the advantages of the top board alteration to the trucks had also been a saving to the general public in addition to that of the Treasury. In reply to Mr. Haynes in reference to bottoms of ballast trucks he said that tuart and wandoo timber was now being used to take the place of other timbers which were more sensitive to wet and heat. In answer to Mr. Cairns it certainly appears to me that the apprentice of to-day does lack the skill of those who learnt their trades years ago, but his technical knowledge having been improved enables him to work machines which were beyond the range of nearly the whole of the youths serving their apprenticeship some 30 or 40 years ago. The insight they now get into other trades or professions if they so desire to do by attending technical classes, either during the working hours such as exist at Midland Junction, where the apprentices are instructed concerning Mechanical Drawing, Mathematics, Electricity, Steam and Chemistry, or by attending evening classes, should at any rate give them greater knowledge of how to go about work in the most economical and satisfactory manner if such is their desire, but I am afraid that all the desires of those who are so taught do not go in this direction.

In reference to the overhead dump being superior to the grab:—Provided that the ground was so arranged that a railway was working on a high level along side of one at a lower level it would certainly pay to have the coal placed into the bin by the higher railway so that it would fall by gravitation into the tenders or bunkers of locomotives at the lower level, but when the high level has to be constructed of timber and breakages occur through derailments over the end etc., the latter is certainly

the most economical although of course, it has its limit of usefulness owing to the amount of coal that can be handled per shift being less than can be handled by means of the over head dump which can dump a number of 25 tons of coal from Hopper trucks instead of 10 or 20 cwt. at one time from a grab. And if it is considered that the W.A. Railway Department had suitable steam cranes for working grabs lying idle and overhead dumps required to be construtced and the material and labor paid forthe difference in capital expenditure that is saved by adopting the latter method will be seen.

In order to overcome the tendency which modern machinery and high speed steel had on the training of apprentices referred to by Mr. Cairns, efforts are made by the W.A. Loco Department by the appointment of instructors in both Workshops and Class Rooms, whose duties are to see that the apprentices are taught not only to do a job in the quickest and most satisfactory, but to draw, mark off and design such work as they are connected with. The oil and waste saving machine commenced working regularly in December 1907. The value of the oil and waste recovered during the 2½ years ended 30th June last was £598 8s. 8d. The cost of making these materials fit for use again during the same period was £190 6s. 11d., leaving a clear saving of £408 1s. 9d., equal approximately to £163 per annum. The old lubricator pads, as before stated, are used to place in the bottom of the axle boxes and their use in this manner undoubtedly saves oil and prevents hot boxes, but the actual money saving cannot of course be stated. Of course it will be understood that the recovered oil is blended with other new oil, and the compound tested before issue to see that it is in accordance with standard qualities. In reference to the carriage of fruit the covered vans referred to are for the conveyance of ordinary produce. Four wheeled louvred vans are constructed for the purpose of conveying fruit and dairy produce. To obtain the air from underneath the vehicle is objectionable owing to that air being charged with dust. Every care is taken to get as much ventilation as possible from the best surroundings. Mr. Cairns must know that the weighbridges are not erected for the purpose of giving the weights of the goods carried to the customers, but to enable the Railway Department to find if the full amount has been charged for the goods by weight.

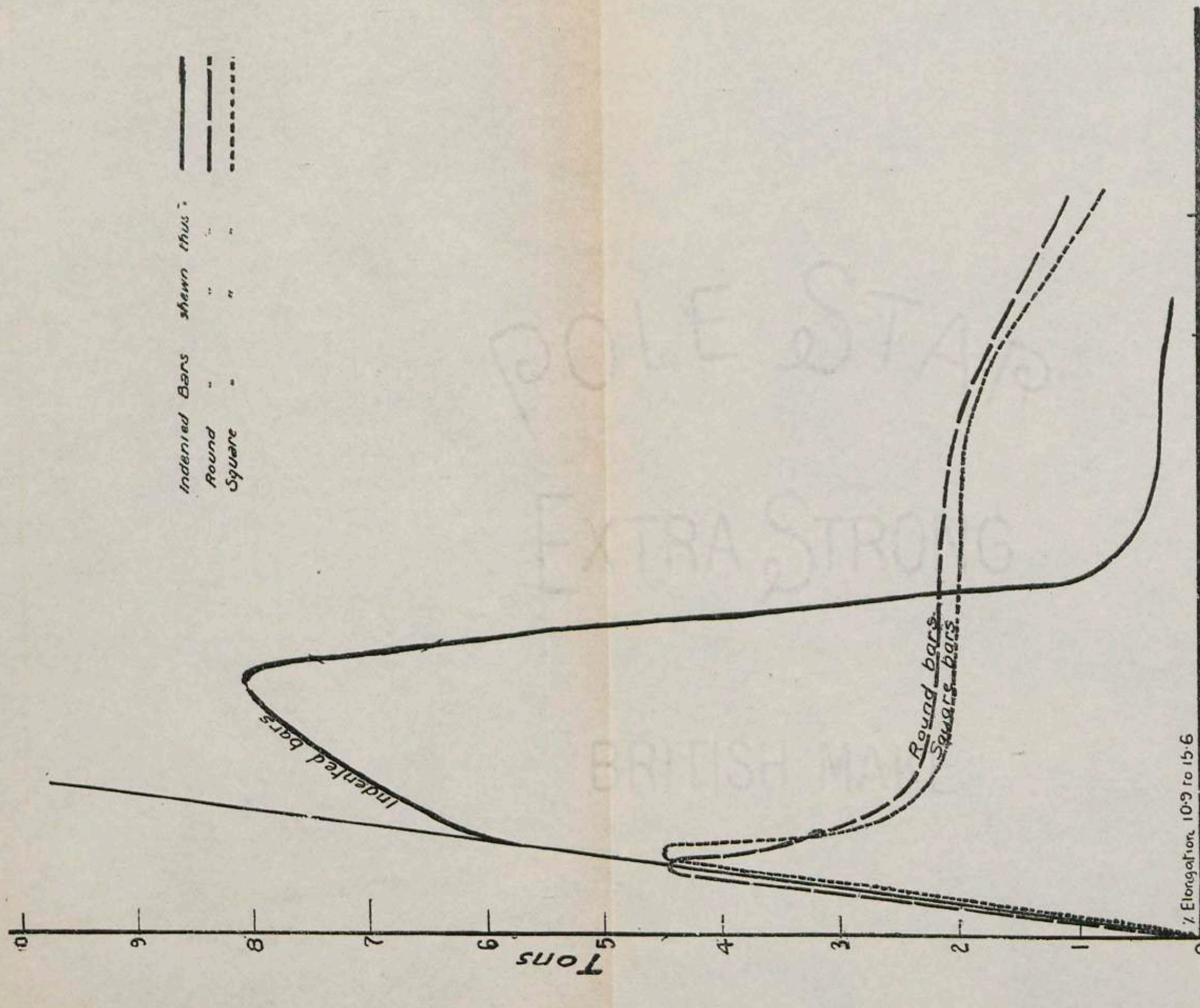


Diagram showing typical failures between indented bars and concrete.

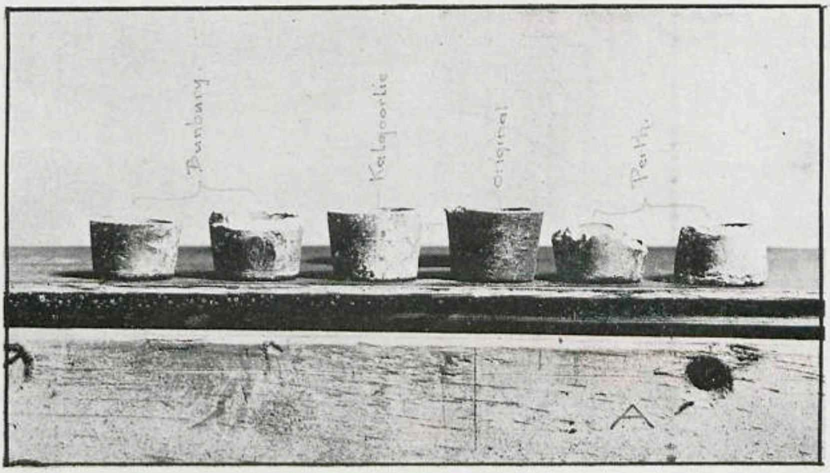
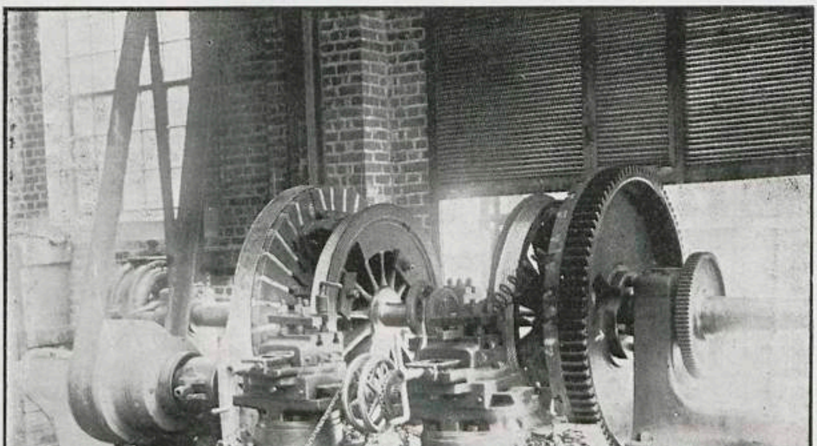


Photo A.



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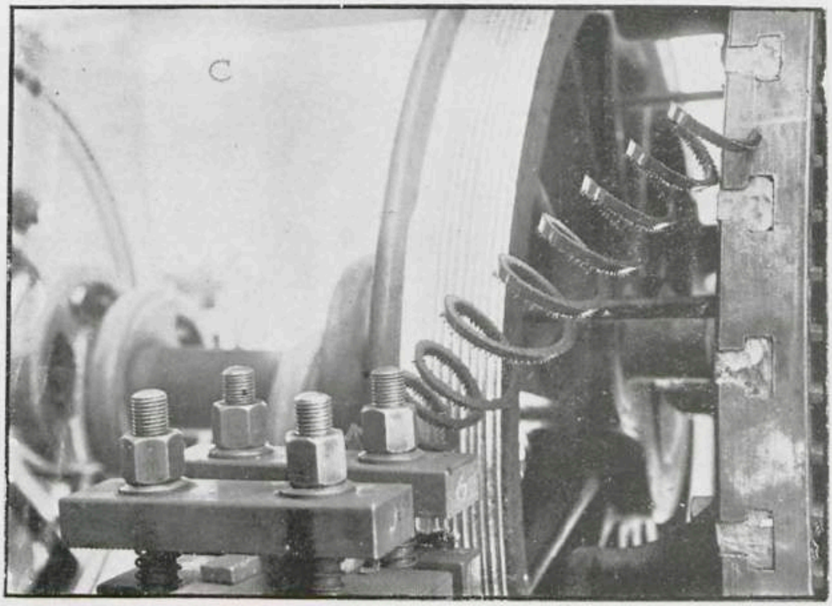

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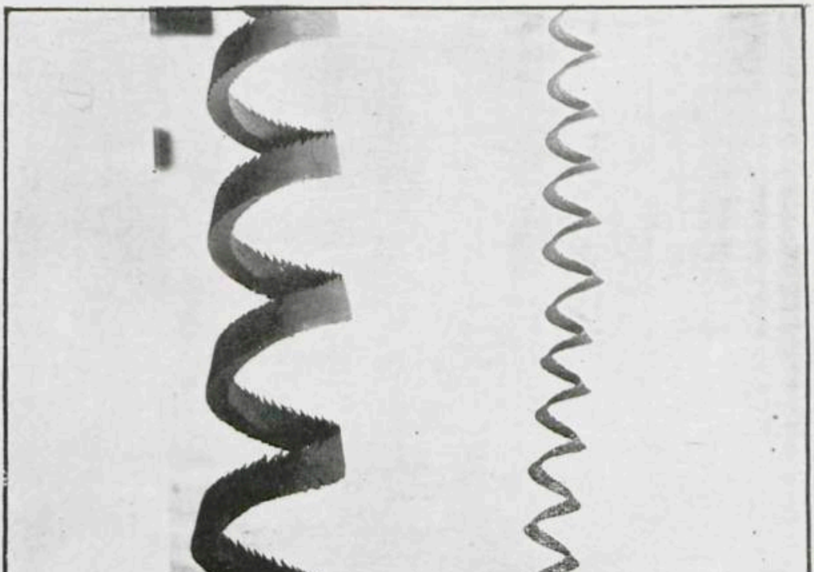

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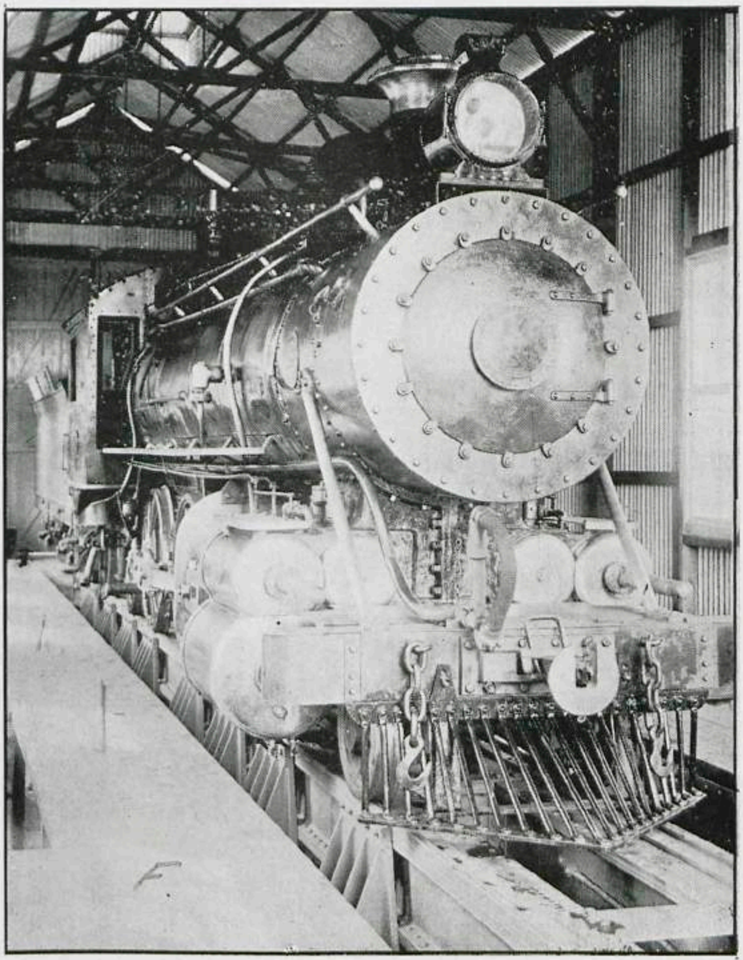

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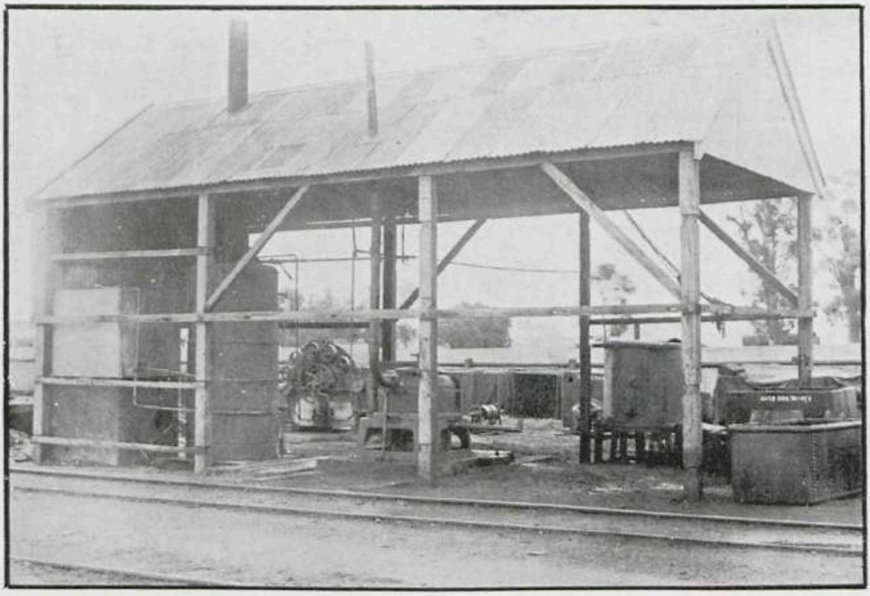

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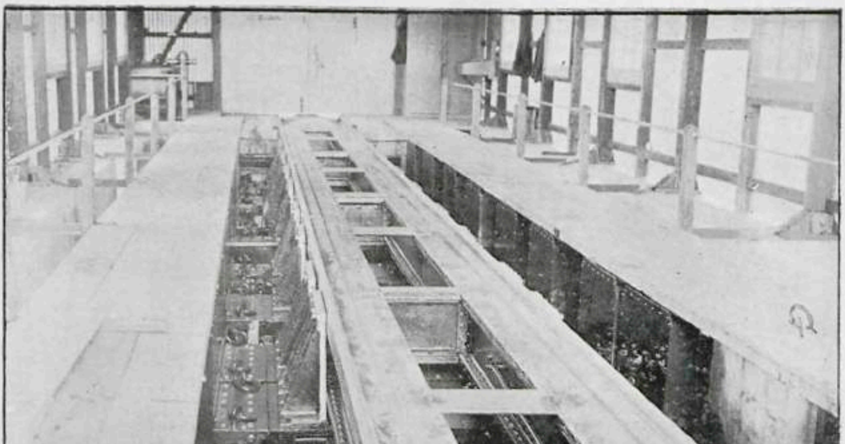

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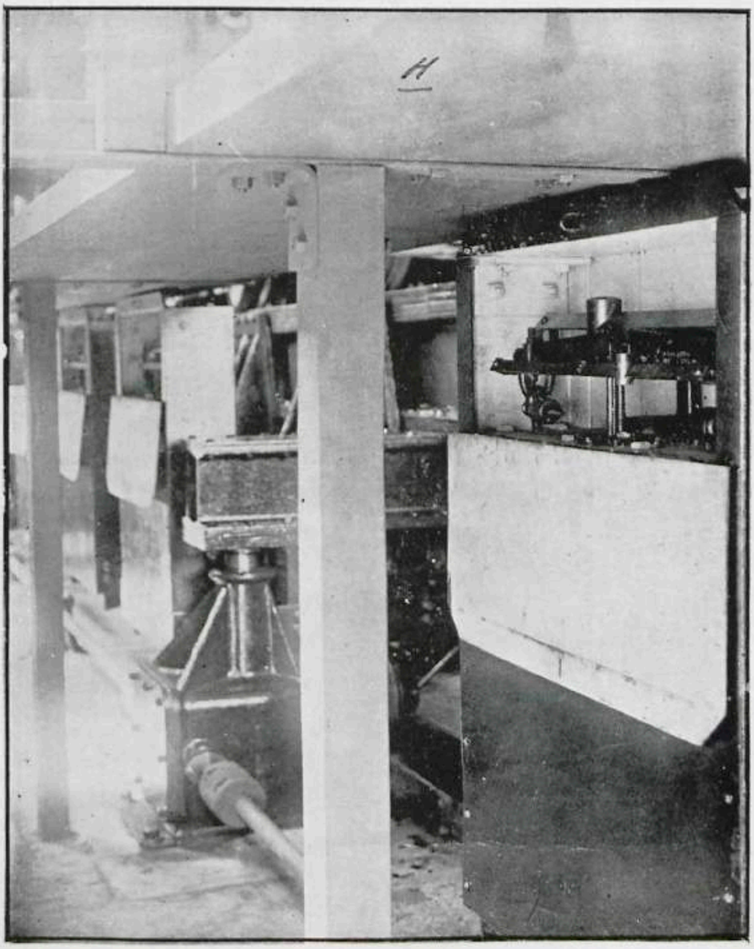

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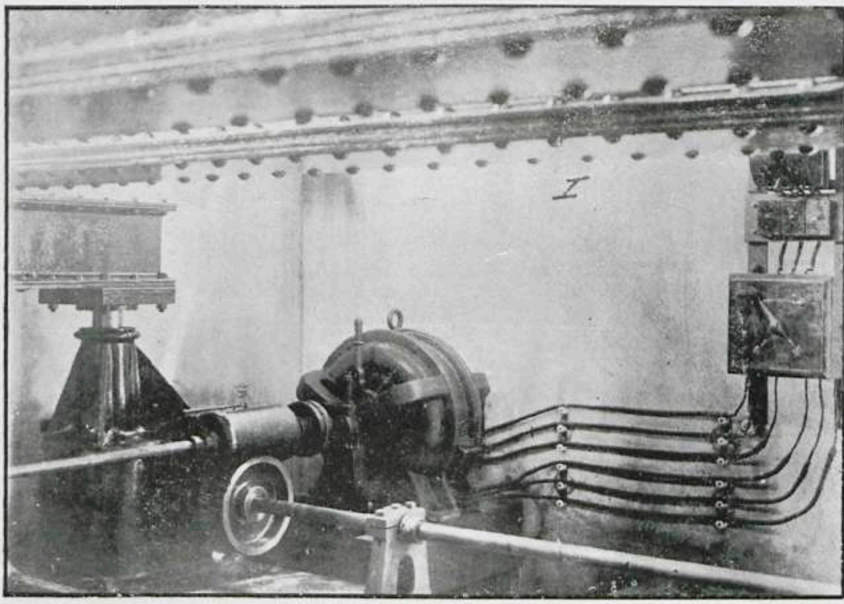
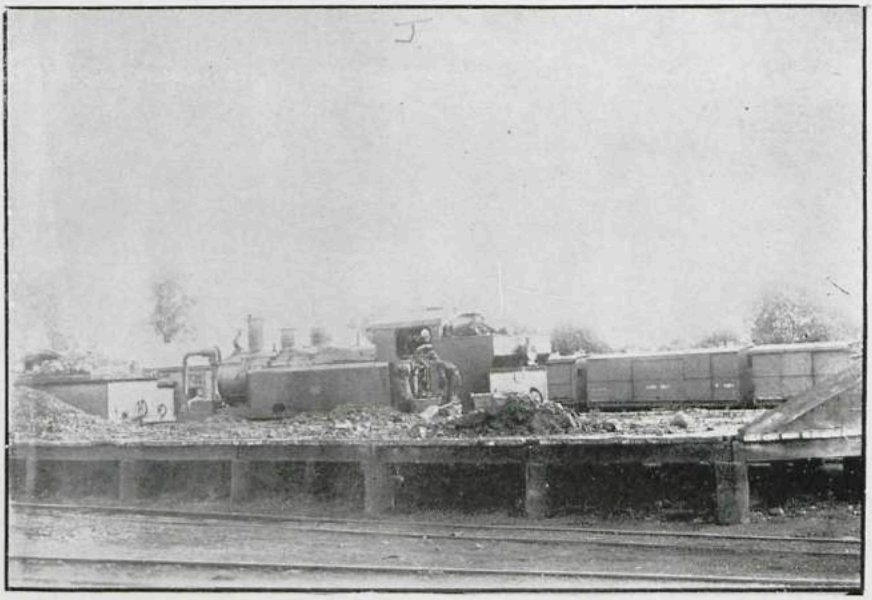


Photo I.



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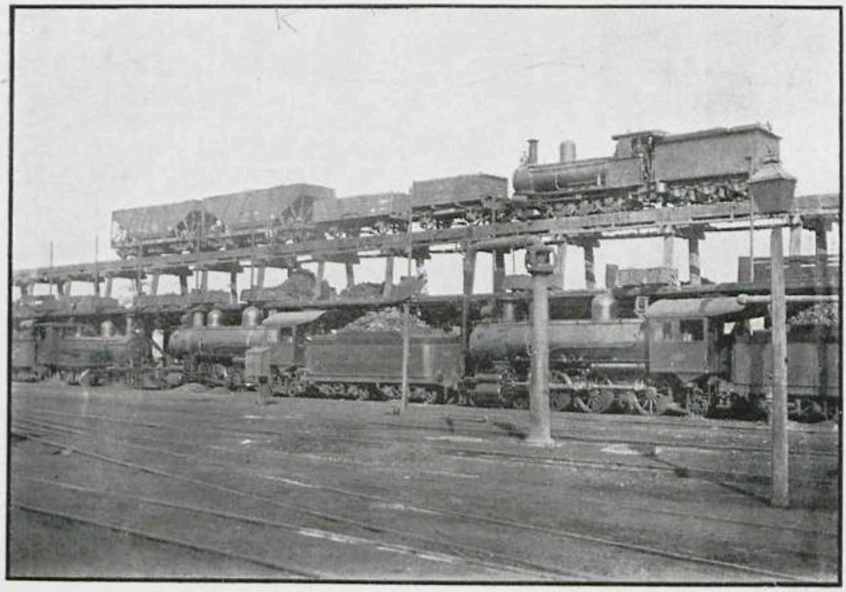

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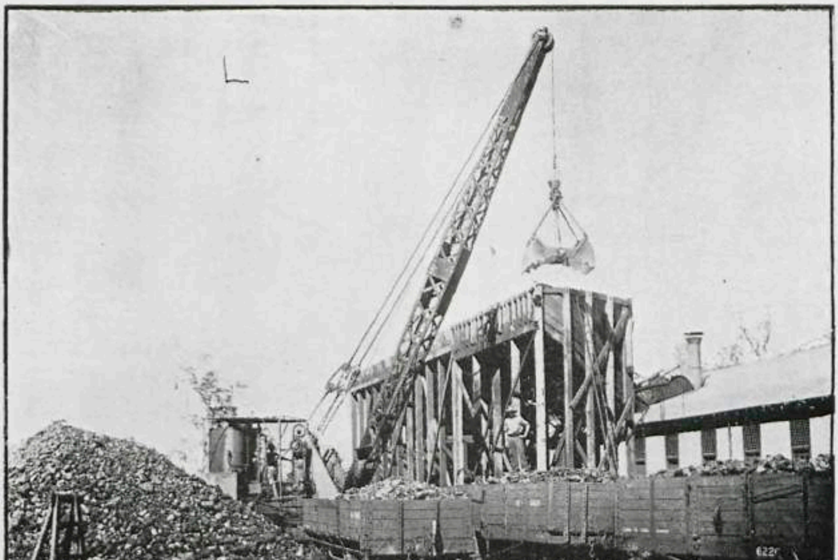

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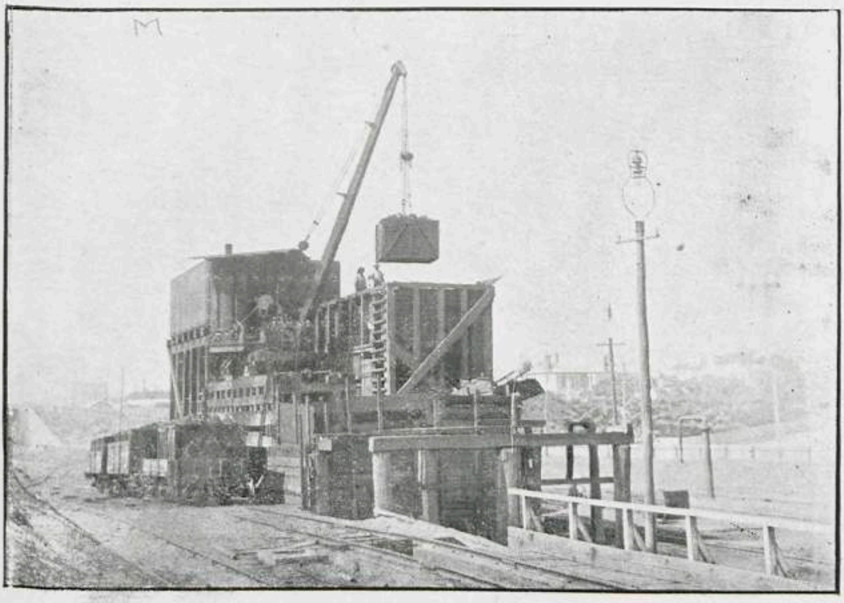

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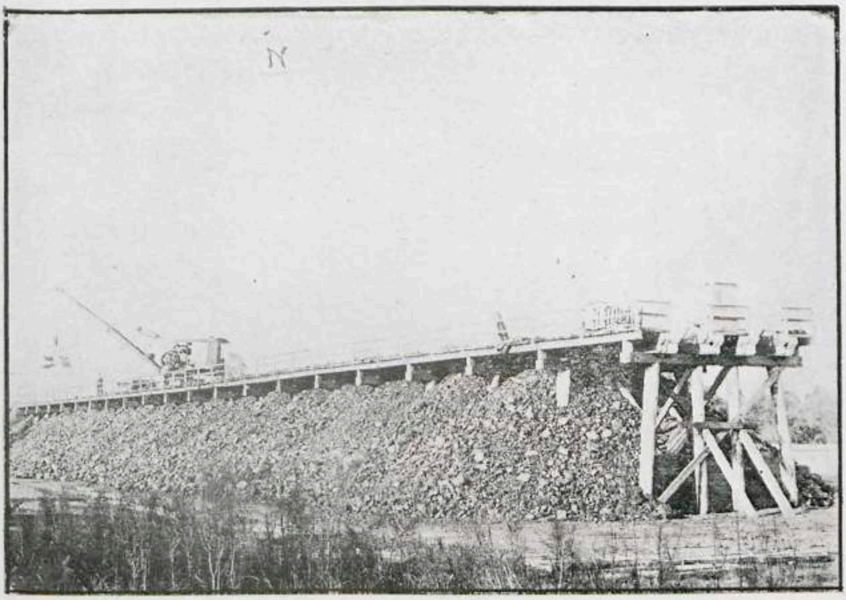

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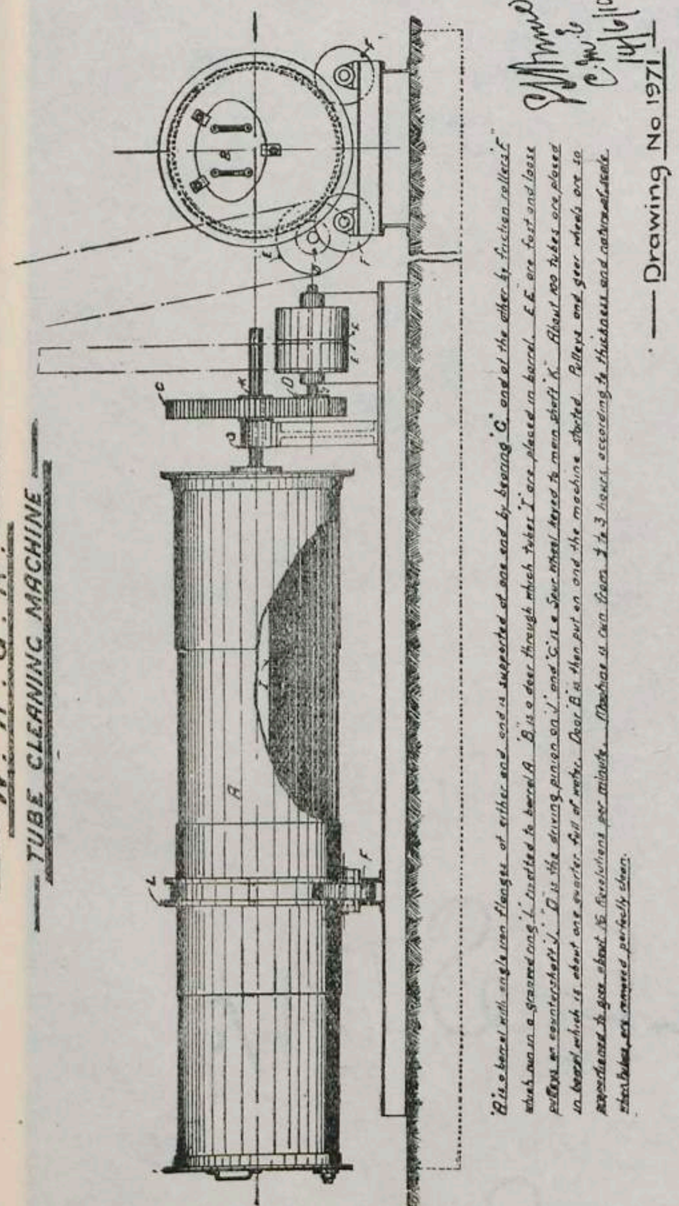
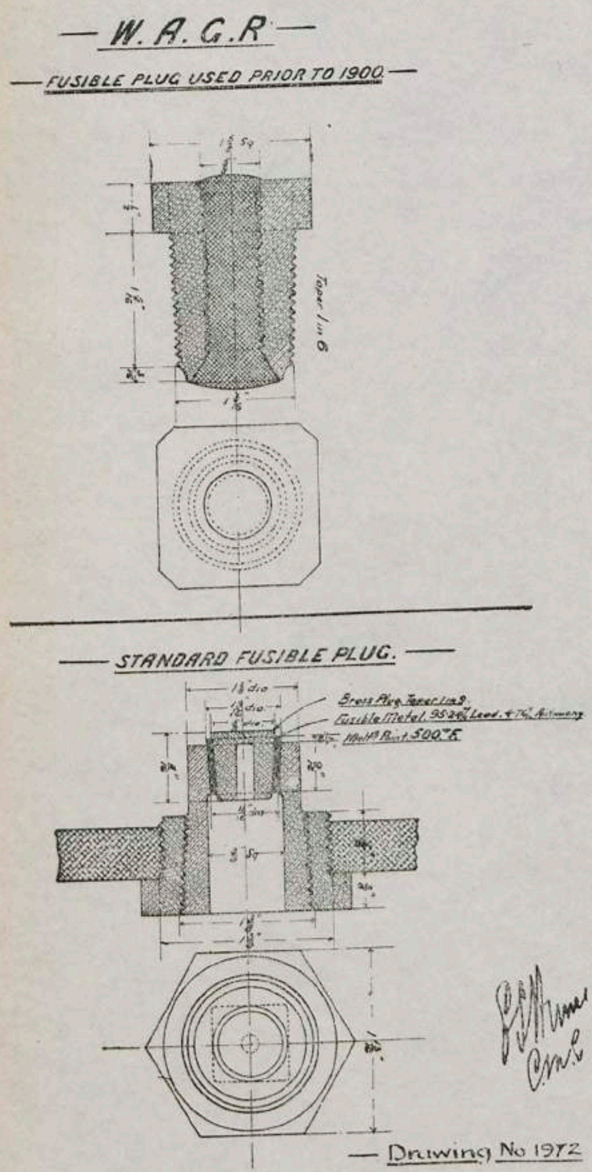
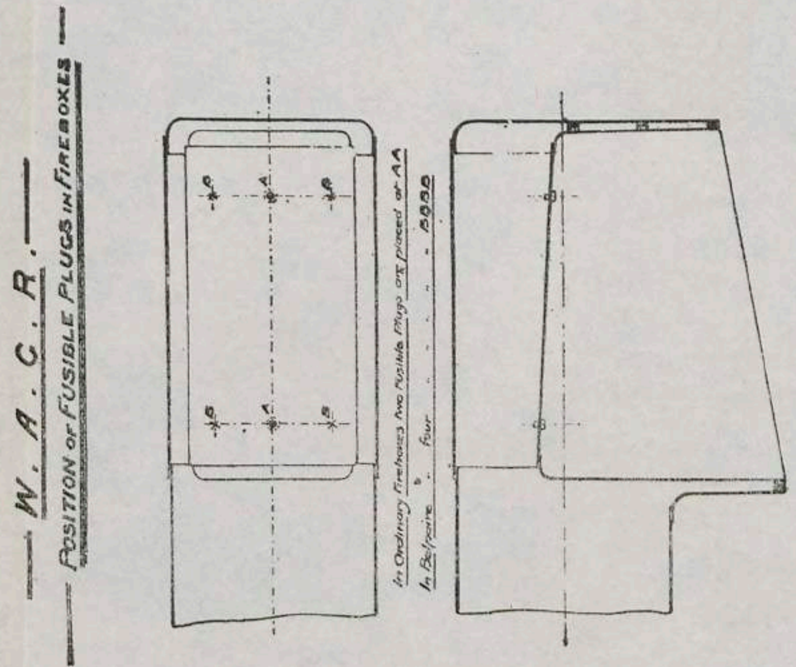


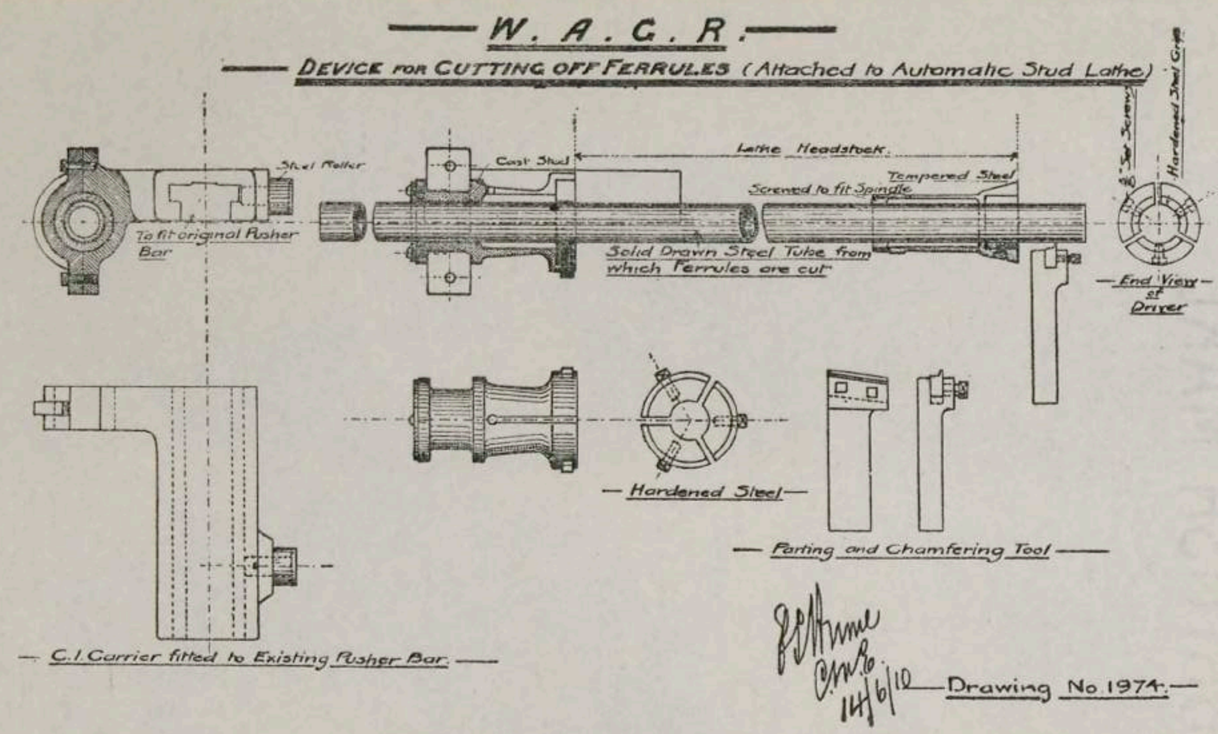
1971.



1972.



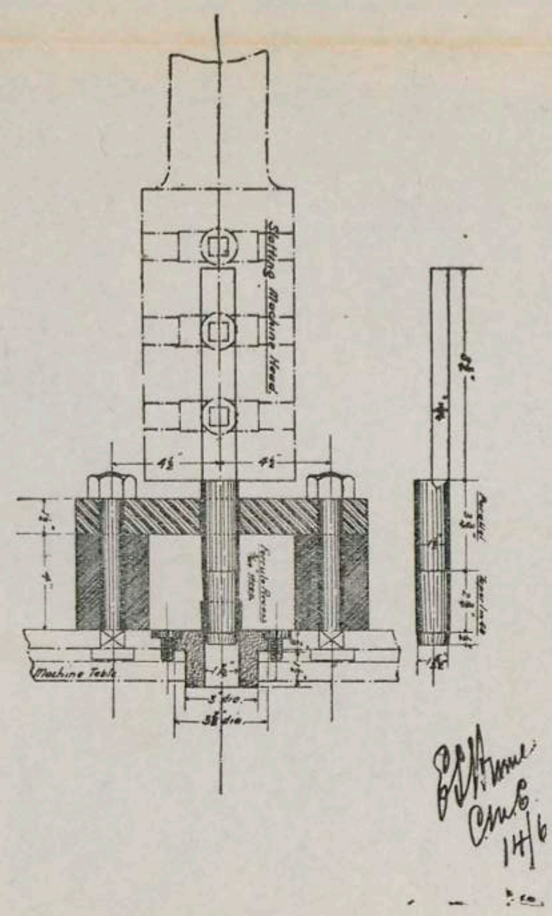
1973.—Drawing No. 1973.



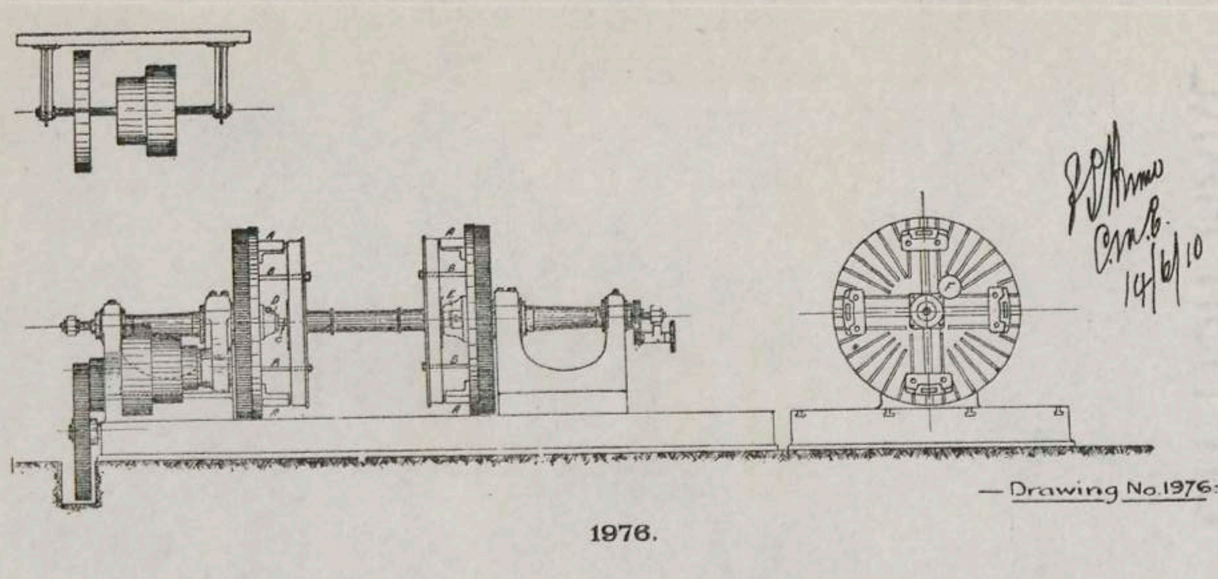
1974.

W.A.G.R.

Device for tapering ferrules in Slotting Machines.

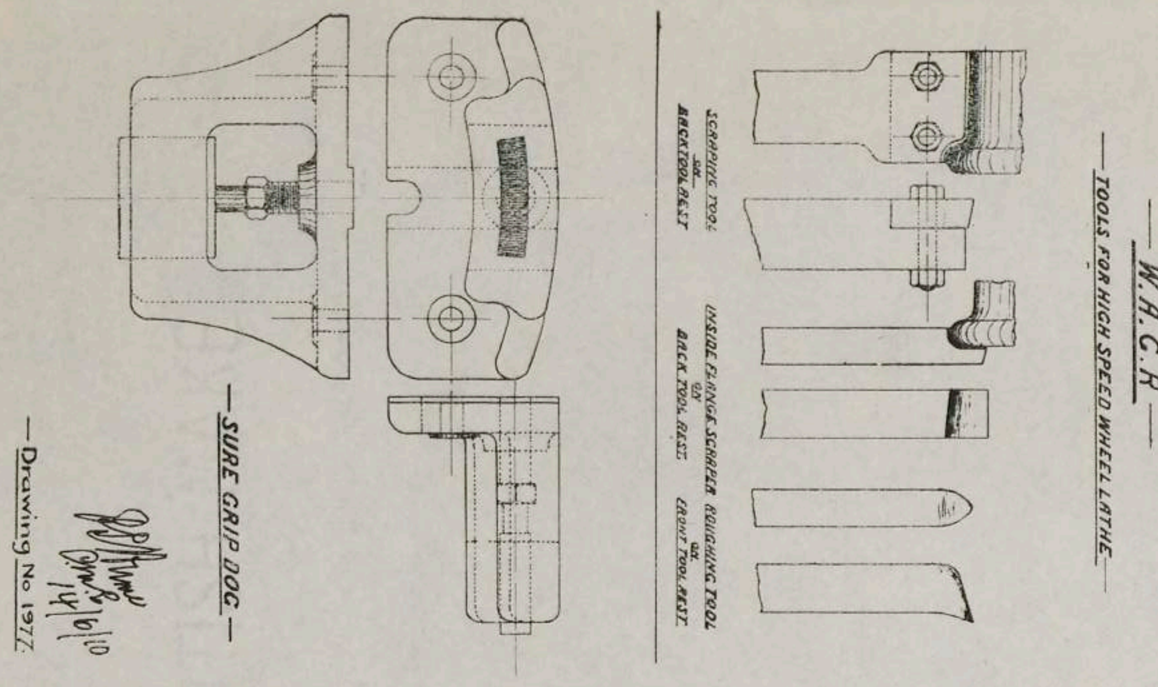


1975.

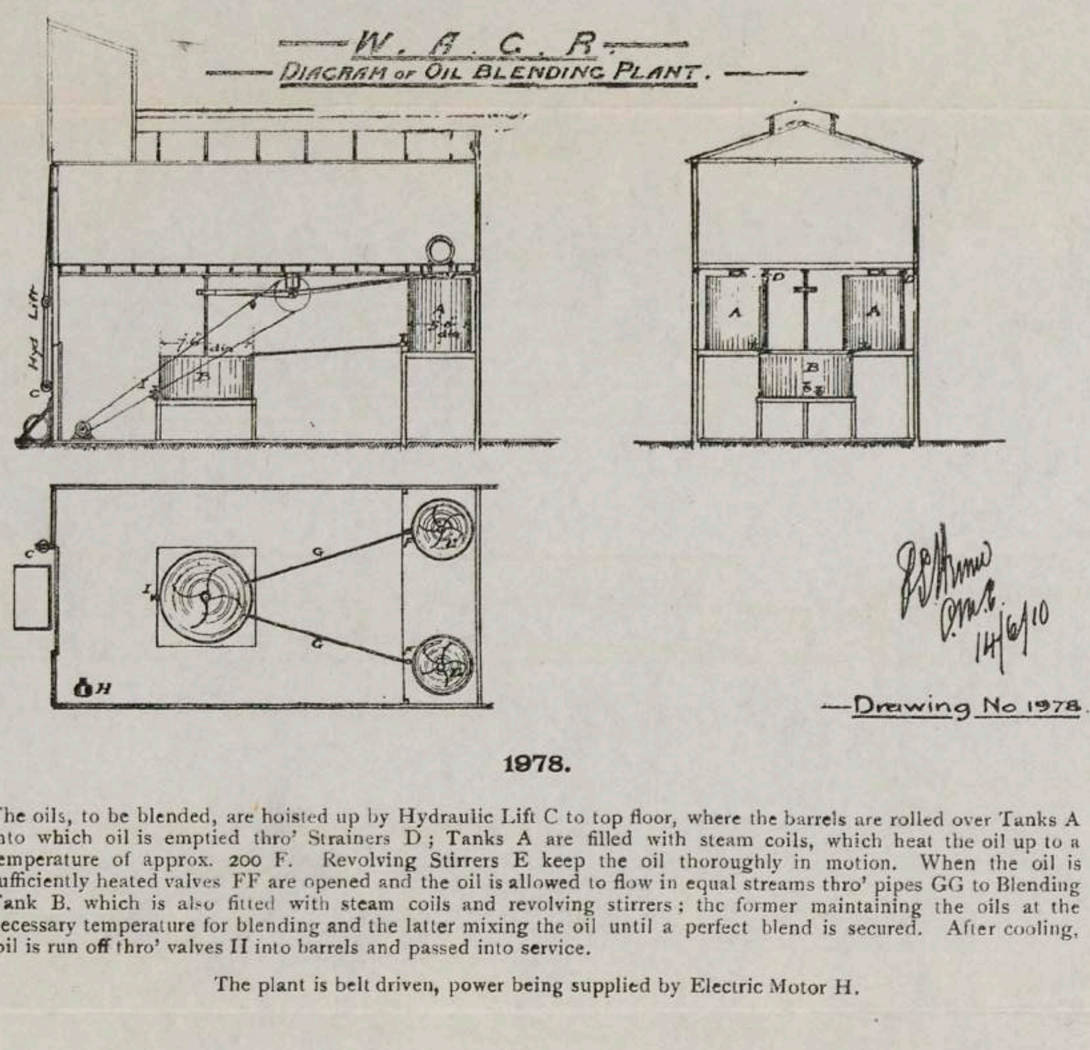


1976.

Face Plates were drilled at F to allow Crank Pins to pass in easily, thus allowing Face plates to be brought closer together. Centre C was made adjustable instead of being fixed as before. Four "Sure Grip" Dogs were fitted. These, when tightened up thro' the agency of Adjusting screw E, grip the wheels securely. In order that the pressure due to Dogs should not distort wheel in any way, Resistance bolts B are used to counteract the thrust. These bolts also assist in securing the wheels. When all dogs and bolts are finally tightened up the wheels are absolutely rigid in the Machine, in fact part and parcel of it. This enables a large cut to be taken off at high speed. Tool rests (not shown in sketch) are fitted on both back and front of Lathe, the tools in the former being, of course, reversed. In the front Tool Rests are the Tools for turning the Treads of Wheels. When this is complete, the operator applies the scraping tool fixed in the back Rest and at the same time turns the Flange with the Tool in the back Rest. This being completed the inside of the Flange is shaped by a Flanging Tool held in back Rests. These operations are carried out simultaneously on both Wheels. A pair of the largest Engine Wheels can be completely turned in one hour.



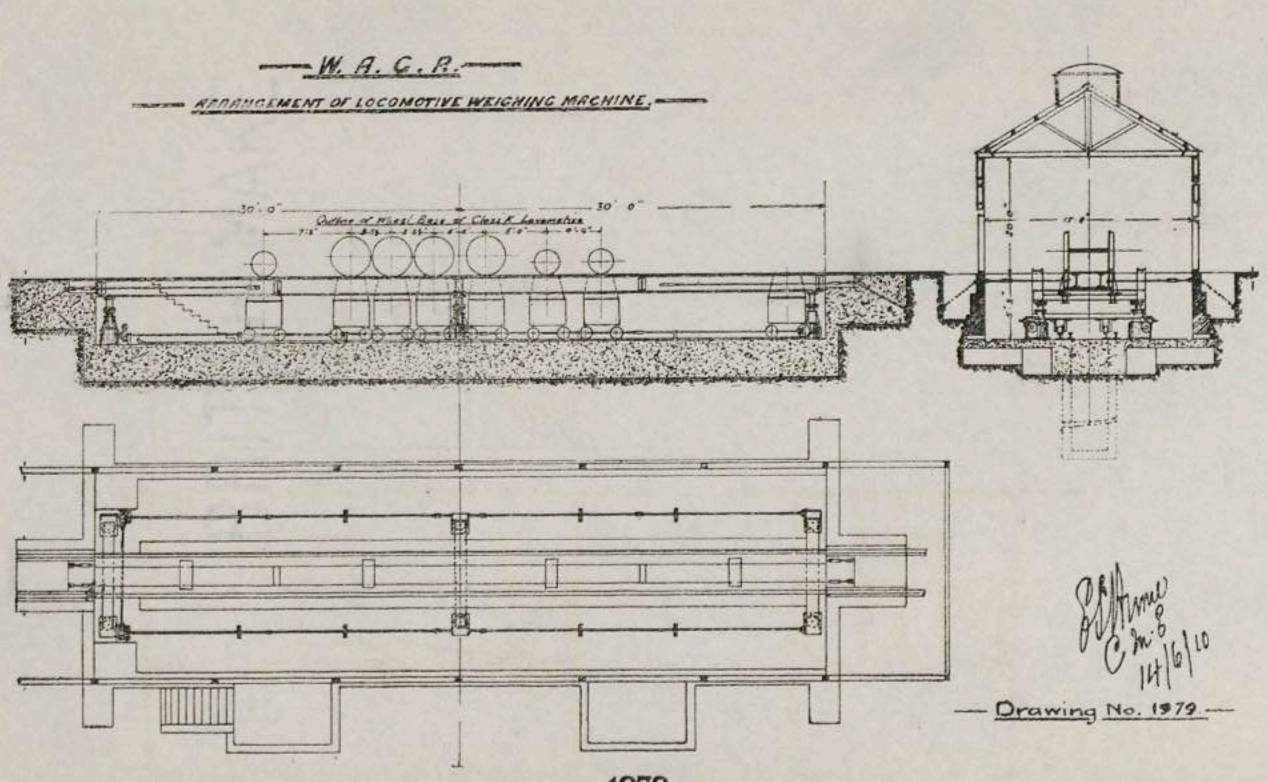
1977.



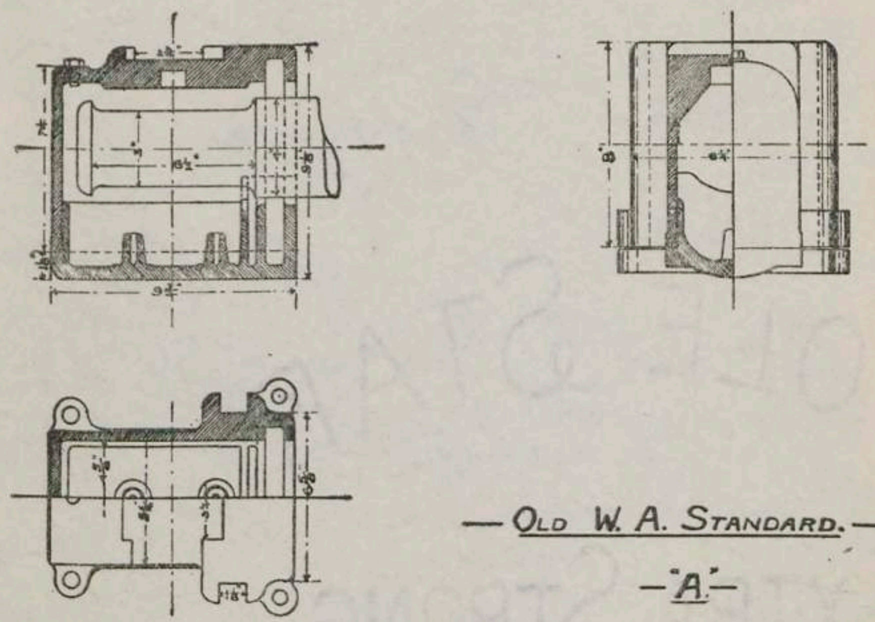
1978.

The oils, to be blended, are hoisted up by Hydraulic Lift C to top floor, where the barrels are rolled over Tanks A into which oil is emptied thro' Strainers D; Tanks A are filled with steam coils, which heat the oil up to a temperature of approx. 200 F. Revolving Stirrers E keep the oil thoroughly in motion. When the oil is sufficiently heated valves FF are opened and the oil is allowed to flow in equal streams thro' pipes GG to Blending Tank B. which is also fitted with steam coils and revolving stirrers; the former maintaining the oils at the necessary temperature for blending and the latter mixing the oil until a perfect blend is secured. After cooling, oil is run off thro' valves II into barrels and passed into service.

The plant is belt driven, power being supplied by Electric Motor H.

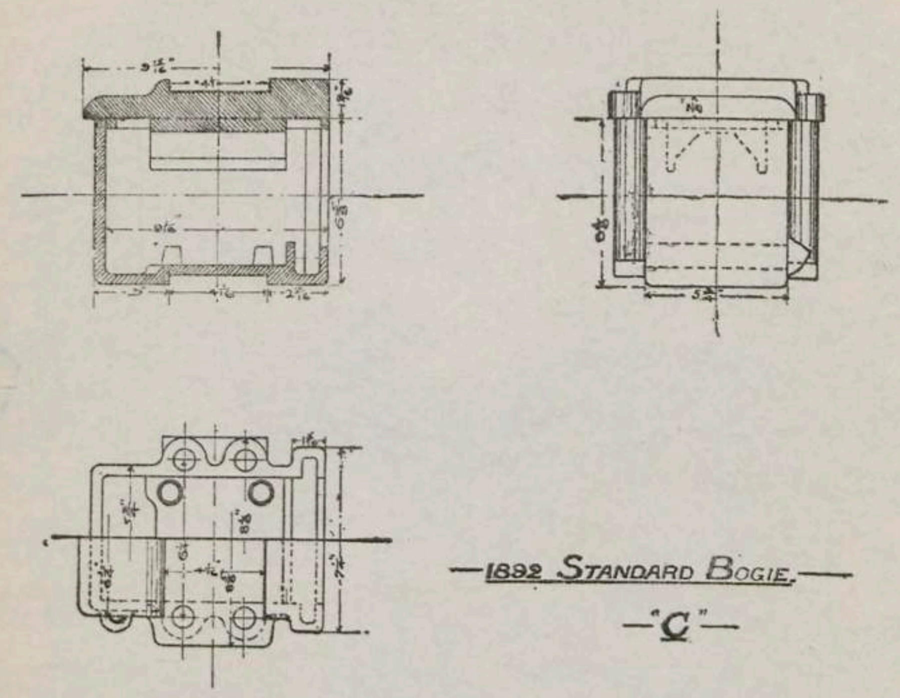


1979.



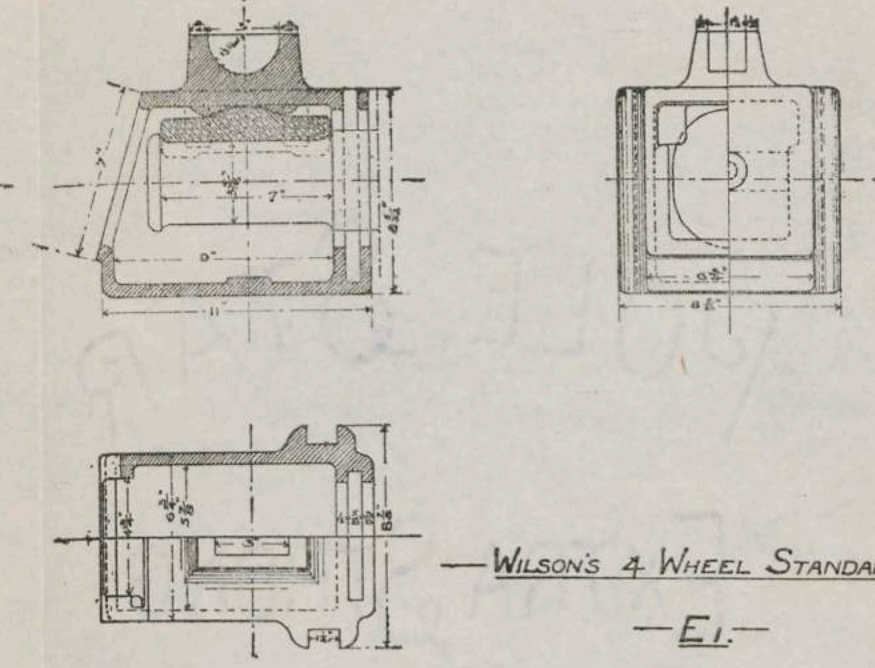
—OLD W. A. STANDARD.—

—"A."—



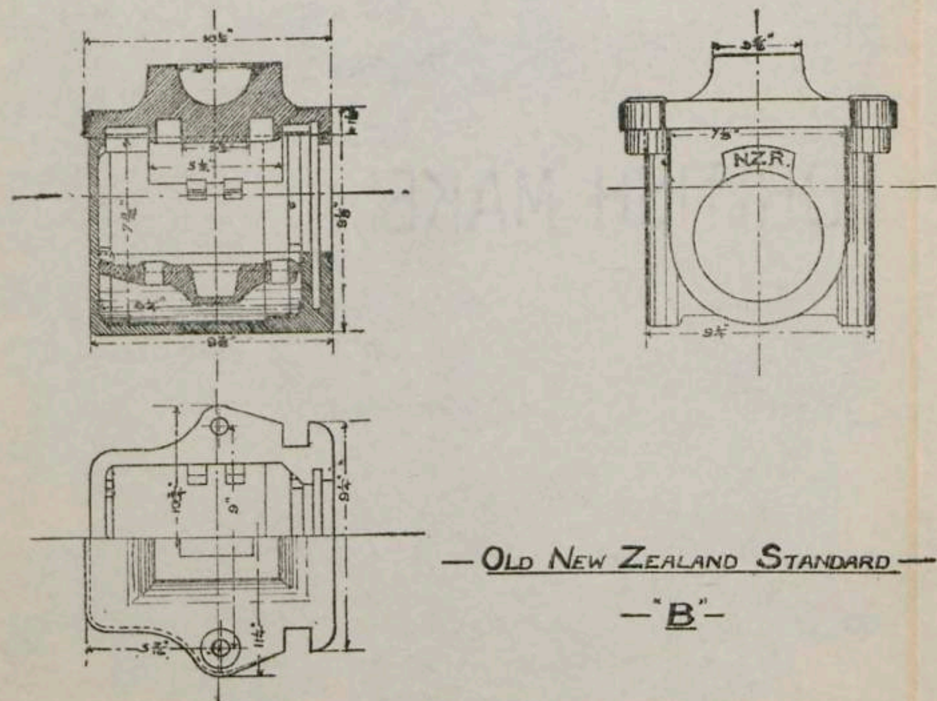
—1892 STANDARD BOGIE.—

—"C"—



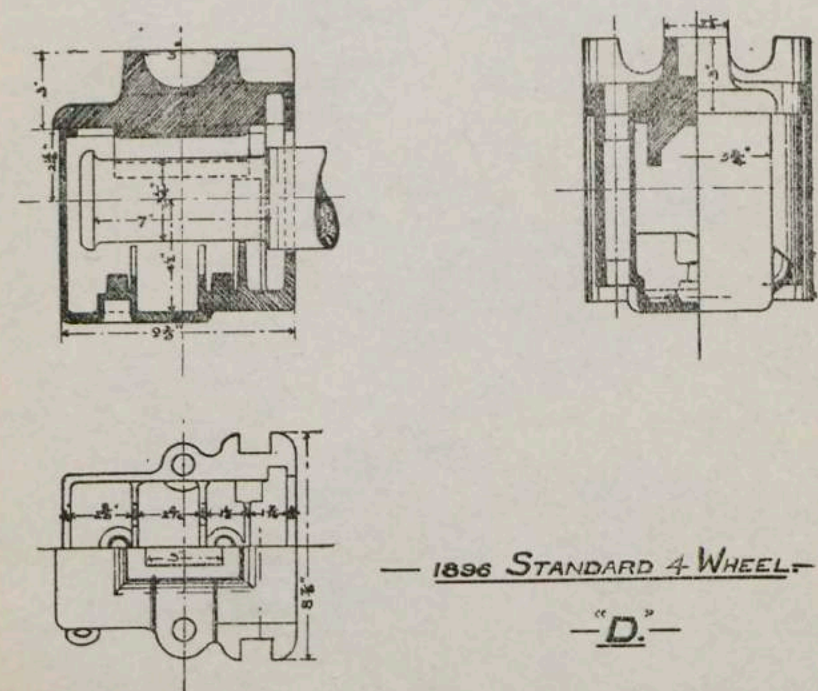
—WILSON'S 4 WHEEL STANDARD.—

—E1.—



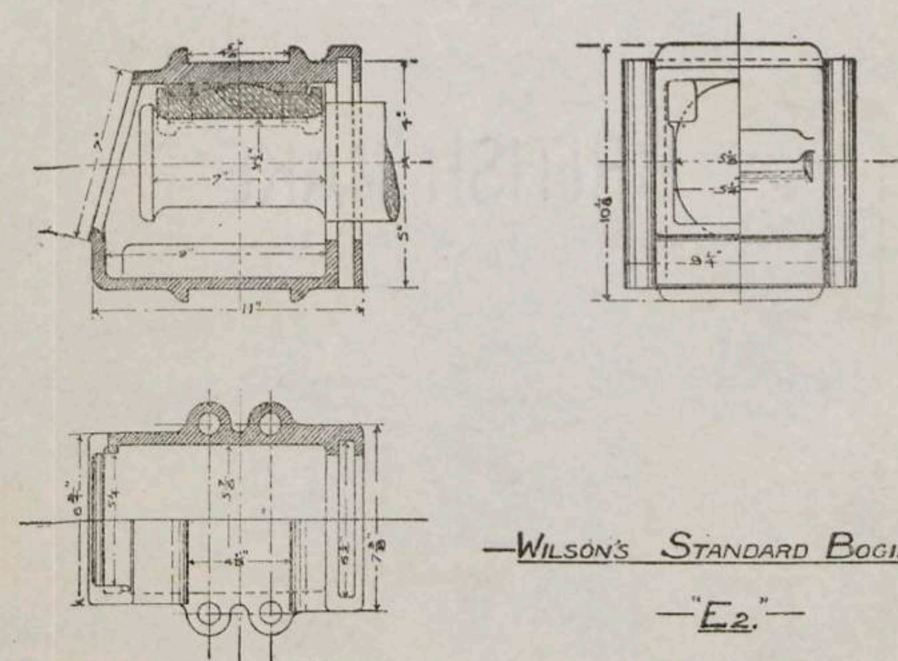
—OLD NEW ZEALAND STANDARD—

—"B"—



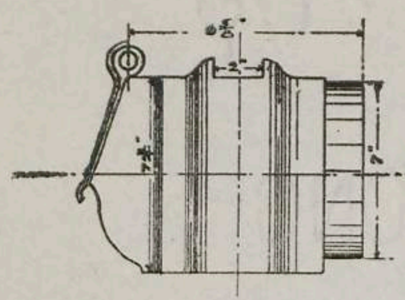
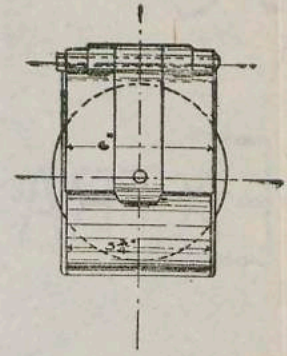
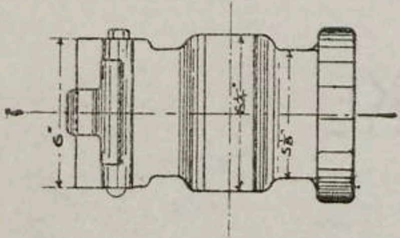
—1896 STANDARD 4 WHEEL.—

—"D."—



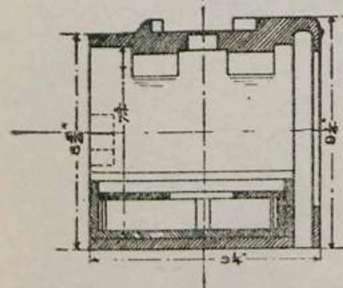
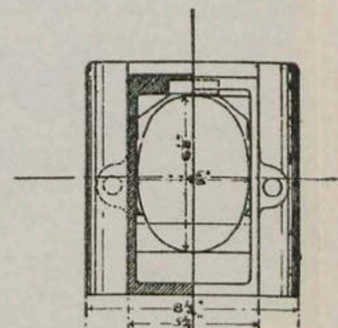
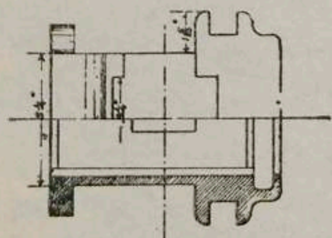
—WILSON'S STANDARD BOGIE.—

—"E2."—

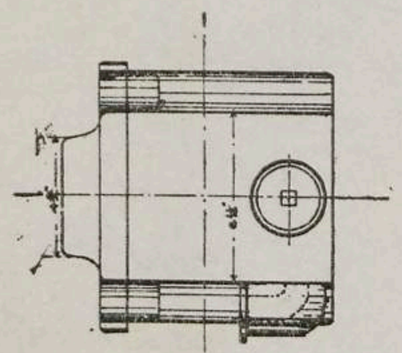
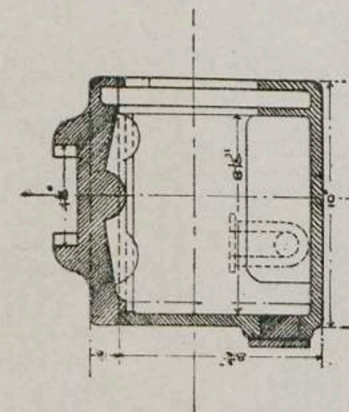
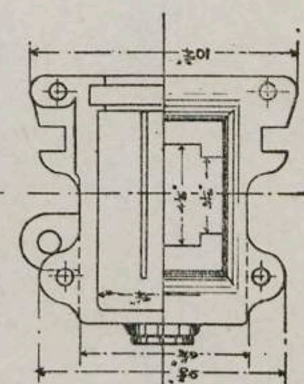
— GILBERT CAR. —

— "F." —

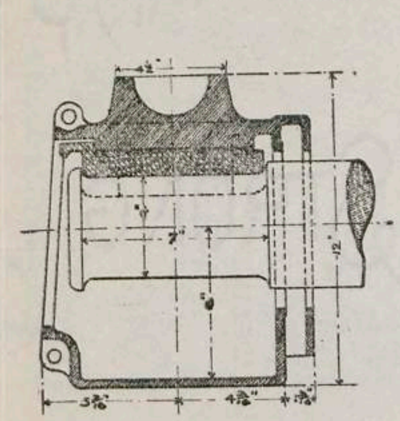
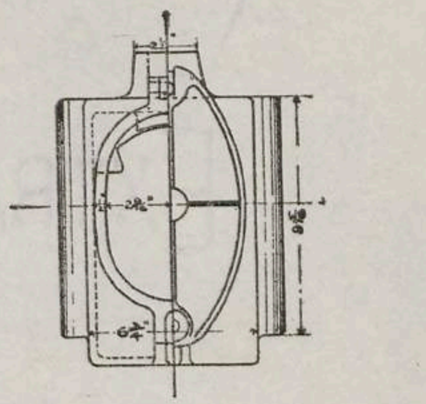
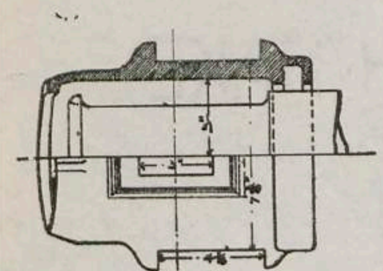
— G. S. RAILWAY. —

— "G." —

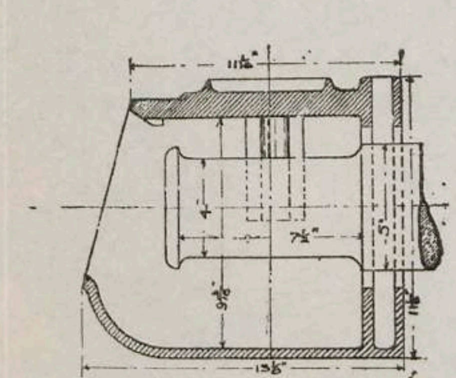
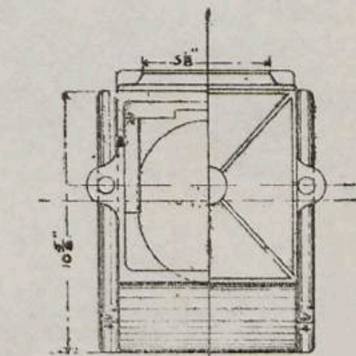
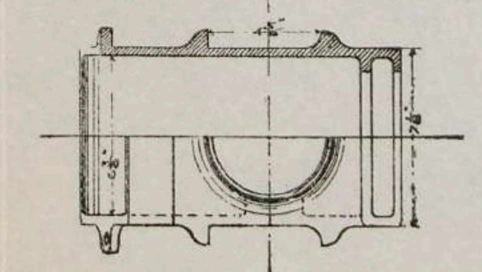
— SOUTH AUSTRALIAN. —

— "H." —

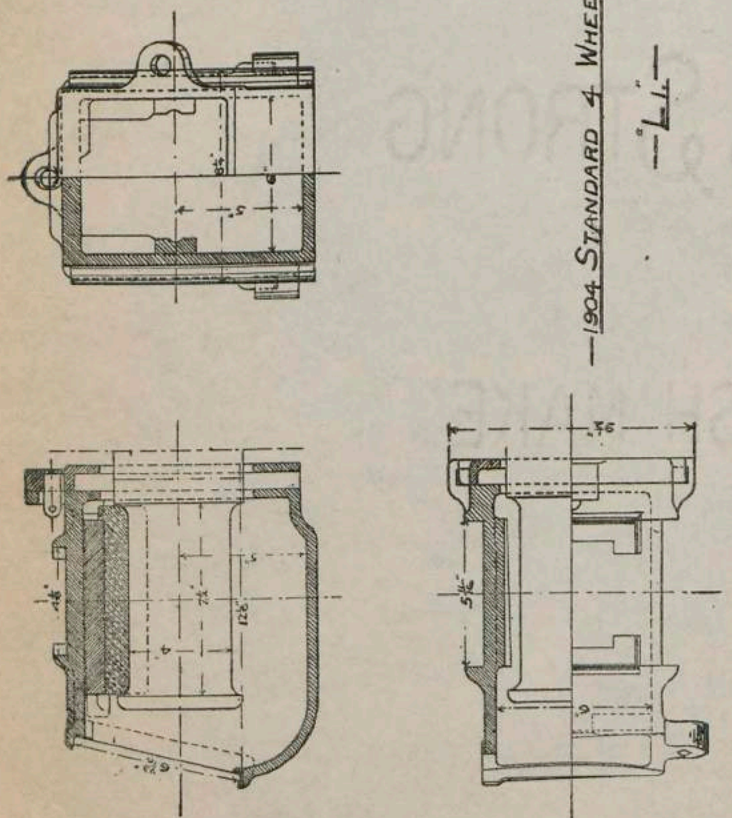
— 1901 STANDARD. —

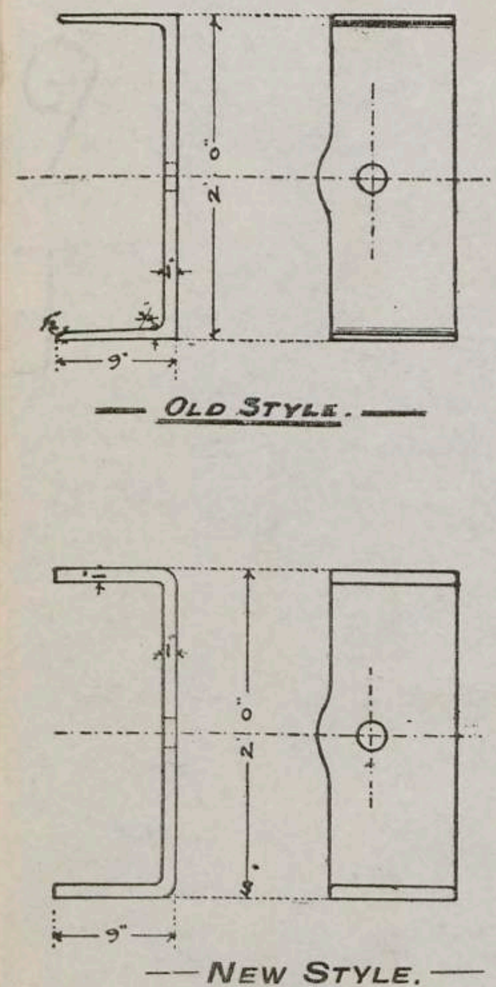
— "J1." —

— AMERICAN CA. —

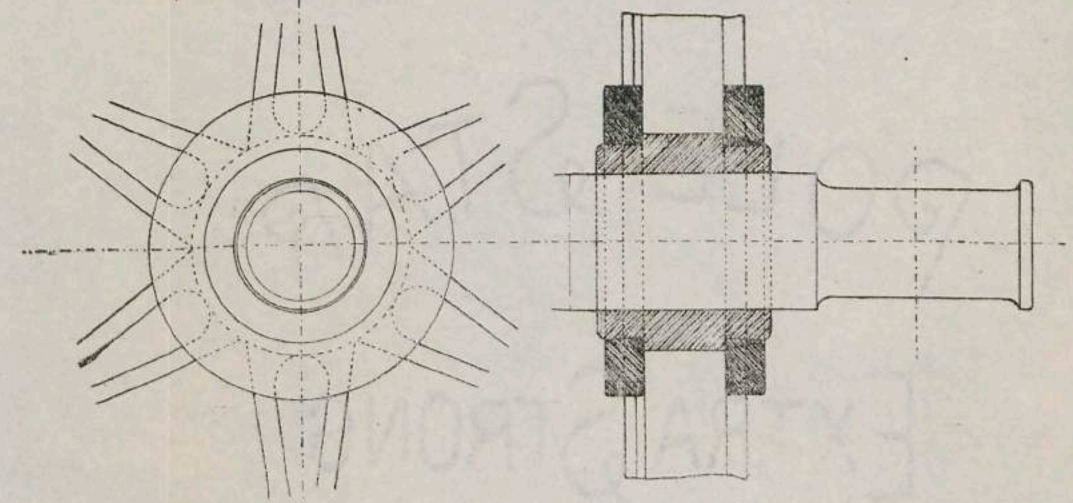
— "K1." —



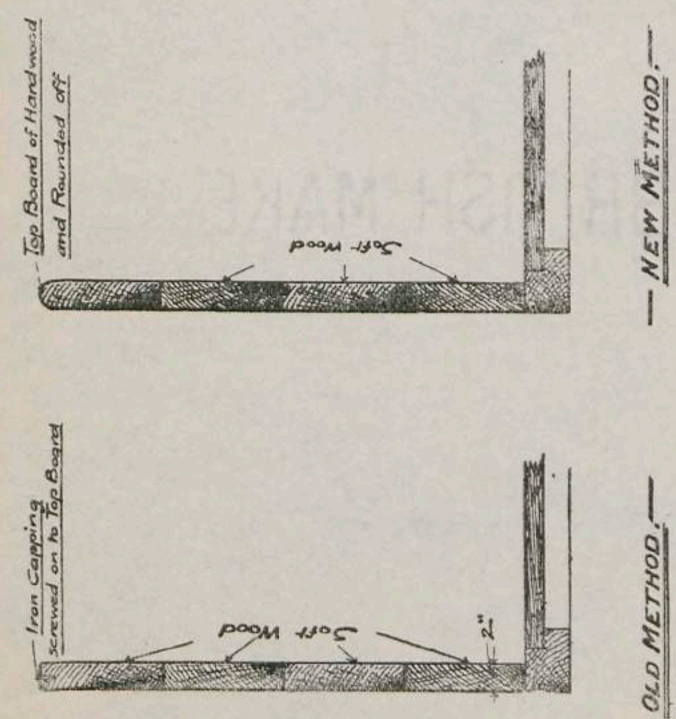


W.A.G.R.
Old and New Styles of Buffer Plates.

Drawing No. 1980.



W.A.G.R.
Banded Wheel. Drawing No. 1981.



W.A.G.R.
Top Boards of Wagon Sides. Drawing No. 1982.

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